THE

GEOLOGICAL MAGAZINE.

NEW SERIES. DECADE III. VOL. VIII.

No. VIII.—AUGUST, 1891.

ORIGINAL ARTICLES.

I.—On the Sands and Gravels Intercalated in the Boulder-clay.

By G. W. Bulman, M.A., B.Sc., Corbridge-on-Tyne.

THE interpretation of the sands and gravels intercalated in the glacial drift is one of the most interesting problems in glacial geology. Do they, on the one hand, represent the deposits of one or more mild intervals alternating with periods of intense cold; or were they, on the other, laid down during one continuous cold period marked by such slight oscillations as can be shown to occur in connection with existing glaciers and ice-sheets?

The former view has been ably advocated by geologists of repute —notably by Prof. J. Geikie—and implies the belief in one or more intervals of mild climate, each comparable in duration to the cold period which it followed and preceded. It is founded partly on the idea that the sands and gravels are due to such aqueous action as would indicate a permanent retreat of the ice; and partly on some few mammalian and other remains found in them.

Prof. Geikie expresses his opinion as follows:—

1. "The till itself is a truly glacial deposit, due to the grinding action over the surface of the country of immense masses of glacier ice. But no one will doubt that its intercalated and subjacent beds of silt, sand, and gravel have had a very different origin. They occur in such layers as could only have been spread out by the action of running water."[1]

2. "We have found that there is abundant proof to show that the accumulation of a *moraine profonde* by one great ice-sheet was interrupted several times; that the ice-sheet vanished from the low grounds, and even from many of the upland valleys, and that rivers and lakes then appeared where before all had been ice and snow. We have also learned that during such mild interglacial periods, Oxen, Deer, Horses, Mammoths, Reindeer, and no doubt other animals besides these occupied the land."[2]

But, admitting such evidence, it is obvious that there must have been not one but several such mild interglacial periods. And so we find Prof. Geikie stating, in his address to the Geological Section of the British Association at Newcastle in 1889, that, "In some places three or more such boulder-clays have been observed over-

[1] "Great Ice Age," p. 165. [2] Ditto, p. 204.

lying one another throughout considerable areas, and these clays are described as being distinctly separate and distinguishable the one from the other." And further:—"Penck, Bohn, and Brückner find evidence of two interglacial epochs, and maintain that there have been three distinct and separate epochs of glaciation in the Alps."[1]

And according to Dr. Croll's views, there must have been a greater number. For his calculations indicate that the glacial epoch lasted 160,000 years, and dividing this into periods of 10,000—the time allowed for a warm interval—we get eight such mild interglacial periods.

Prof. Geikie himself divides the ice age into periods as follows:[2]—

1) Pre-glacial mild period...	First bed.
2) First glacial period	Cromer Clay and contorted beds.
3) First interglacial mild period ...	Sand and rolled gravel above Cromer clay.
4) Second glacial period	Great chalky boulder-clay, etc.
5) Second interglacial mild period ...	Beds between great chalky boulder-clay and purple clay.
6) Third glacial period	Purple clay, lower boulder-clay of Lancashire.
7) Third and last interglacial mild period	Hessle gravel, middle sands, etc., of Lancashire.
8) Last glacial period	Hessle clay, upper boulder-clay of Lancashire.

With regard to the first point in the evidence, two suggestions occur:

(1) Beds of sand intercalated in the till *may* be in part the result of the action of the ice itself. In fact, if we do not so regard them, the composition of the till and boulder clay is a difficulty on the usual hypothesis of its origin. The products of glaciation are supposed to be these clays, and morainic debris: that is to say, very finely ground rock matter, forming the clay, with large and small stones making up the rest of the till and the morainic matter. But in the process of grinding down there must have been an intermediate product, viz. coarse and fine sand; and if these are not represented by the intercalated sand beds, where are they? And even if all the rock matter excepting the boulders and pebbles had been ground down to the fineness of the sediment forming the clay, it is difficult to understand how a purely siliceous sand could ever become plastic, and form a clay. For although the glacial clay is at times sandy, its general composition does not permit the supposition that it contains all the sand produced by the grinding down of the rocks by the ice. In fact, it seems almost certain that sand must necessarily be one of the results of ice action; and that it should occur interstratified with the till is as natural as that in a river deposit sand should be intercalated with gravel.

And in his "Ice Age in North America," Dr. Wright speaks of "the sands and gravels of the terminal moraine" of the Muir glacier (p. 47).

[1] See Brit. Assoc. Reports, 1889, pp. 556–558.
[2] Great Ice Age, p. 393.

(2) The products of stream and ice action would necessarily be mingled *during* the continuance of the cold period. For, during summer, ice action would give place to that of water near the termination of the ice-sheet or glacier; and thus truly aqueous deposits would be formed over the glacial, to be in turn overlaid by the latter.

A succession of exceptionally warm summers, too, might cause the temporary retreat of the ice—just as in recent years a succession of exceptionally severe winters caused the formation of a veritable glacier in one of the Scotch valleys—and permit of the formation of a thicker series of sands and gravels.

And as near the extremity of a glacier or ice-sheet stream action takes the place of that of ice every summer, and to a more marked extent during a succession of warmer seasons, so we should expect to find the retreating ice, as the glacial epoch passed away, followed by a series of mixed fluviatile and glacial deposits.

And as oscillations in the extent of existing glaciers are well known, so we naturally infer it was in the past.

As regards the present day, Prof. Prestwich quotes the case of a glacier which has advanced a mile in a century, and that in a region where there is a general retreat of the ice.

And Mr. Lydekker, in his account of the Geology of Baltistan, Kashmir, describes one glacier which is retreating, and another which is advancing. Thus of the Tápsa glacier he writes:

"A comparatively modern terminal moraine, forming a dome-shaped hill covered with cypress, bounds the cultivated ground superiorly; above this old moraine is the present terminal moraine of the glacier. The above appearances seem to indicate that the Tápsa glacier has receded by small gradations, pausing here and there, until it finally attained its present shrunken dimensions."

But of the Palma glacier:

"The present Palma glacier shows pretty evident signs of being on the increase, since it terminates inferiorly in an abrupt and precipitous wall of ice, with but comparatively little debris and no distinct terminal moraine, which seems to have been overflowed and, so to speak, swallowed up by the glacier."[1]

The possibility of lacustrine action in glacial times is also suggested by the usually received interpretation of the parallel roads of Glen Roy. These are held to have been formed by a lake caused by the blocking up of the lower part of the valley by ice. While the lake stood at different levels, the action of the water formed a series of shelves on the mountain side along the margin of the lake. But it is difficult to resist the conviction, that if the lake was fed by streams, more or less lacustrine deposits would be formed in it: in other words that gravel, sand, and silt would be laid down, and afterwards overlaid by typical glacial deposits.

And stream action also, it is well known, occurs *beneath* the ice-sheet and glacier. Springs, for example, issuing from the ground beneath the ice, will cut for themselves channels through it. The

[1] Records Geol. Surv. India, vol. xiv. pp. 44–45.

great thickness of the ice itself prevents the intense external cold reaching such springs, and they may continue to flow during the cold period. We may even speculate on the probability that in those ancient days, so much nearer the period of Tertiary volcanic activity, *warm* springs were more numerous and powerful than they are to-day. At first sight the suggestion doubtless arises, that the springs would lack their usual source of supply, and early in the glacial period become dried up. But, in the first place, the surface ice is constantly melting, and the water at times sinking down through cracks to the bottom; and, in the second place, ice melts through pressure and friction such as occur beneath an ice-sheet or glacier. These two sources of supply might still feed the springs, and serve to increase the streams formed by them.

The possibility of stream action beneath a great continental ice-sheet is indicated by a study of that of Greenland. Explorers describe surface rivers cutting for themselves channels between banks of ice, and all finally disappearing by plunging down through openings in the ice to the bottom.[1] These rivers then probably flow along sub-glacial channels to the extremity of the ice-sheet, eroding the rocks, and forming fluviatile deposits as they go.

In connection with this, it may be noted, that it is held by many that more heat was received from the sun during the summer of the glacial epoch than at present, and that consequently this surface-melting, and formation of rivers would be on a larger scale.

And in "The Ice Age in North America," Dr. Wright notes the occurrence of *water-worn* débris on the ice of the existing Muir glacier: "Here a vast amount of water-worn *débris* covers the ice, extending up the glacier in the line of motion for a long distance."[2]

The streams issuing from the extremity of the ice, indeed, whether glaciers or ice-sheets, are frequently not formed merely by the melting of the ice at the extremity, but are actually rivers which have run for considerable distances beneath the ice.

Thus, writing of the glaciers of the Alps, M. Rendu describes streams running beneath the whole of that portion of the ice-river which descends below the line of perpetual snow:

"When we traverse the Glacier des Bois, at the bottom of each crevasse we admire a little stream of fresh and limpid water, which appears to flow over a surface of emerald. These streams reach the edges of the glacier, lose themselves among the stones of the *moraine*, and unite again beneath the ice at the bottom of the hollow which contains it. Other streams reach the same destination by the openings which penetrate to the bottom of the glacier; and, lastly, springs and waterfalls fall also upon the banks of the icy river, and take the same direction; so that we are sure that there is a *subterraneous river* which flows beneath the whole extent of the glacier, and which comes to light only at its lower extremity."[3]

And what we must, I think, regard as an example of the mingling of aqueous deposits with glacial occurs in the drift, near London.

[1] Nordenskiöld, Geol. Mag. Vol. IX. p. 393. [2] p. 62.
[3] "Glaciers of Savoy," Translation. Edited by Prof. George Forbes, pp. 156–7.

In describing the middle glacial beds, Mr. Whitaker writes: "Besides these, however, there is sometimes a layer of true Boulder Clay in the gravel, that is, a clay that contains irregularly rounded fragments or boulders of various rocks, the surfaces of which are furrowed and scratched in the way that is peculiar to stones that have been dragged along by masses of ice over a floor of rock. This clay being like that which occurs in force above the gravel, serves to link the two deposits together, and to show that the glacial conditions which seemed to have reigned supreme during the great mass of Boulder Clay existed also during the deposition of the lower bed, though to a less extent." [1]

This *layer* of Boulder clay *in* the gravel can hardly be considered as the product of a glacial epoch, followed and preceded by a mild epoch when gravel was laid down.

And there is another way in which true river sands and gravels may be intercalated in glacial beds without the intervention of a warm interglacial period. They may be *preglacial river deposits* pushed on by the advancing ice over boulder clay already laid down.

Such preglacial river sands and gravels must have been abundant, and it is usually believed that a part of the work of the ice was to sweep these down the valley. What more likely than that some of these deposits, thus pushed on, would be stranded in some quieter spot and *at times* left on the surface of already deposited till?

In writing of the glaciation of South Lancashire, Mr. A. Strahan speaks of the Boulder clay as "sometimes rudely stratified," although "usually devoid of such lamination as is shown by clays deposited freely in water." [2]

He thus further describes the alternation of sheets of Boulder clay with sand and gravel in certain districts:

"In every case where the drift attains any thickness, as in a preglacial river-valley, or the maritime plain of North Flintshire and Denbighshire, it is found to consist of alternations of sheets of Boulder-clay with sand and gravel, the beds running sometimes for a mile or two without interruption." [3]

Here, again, we cannot suppose each sheet of Boulder clay to represent a glacial epoch, and each separating gravel a mild period; we are rather bound to conclude that the glacial conditions which produce Boulder clay are able also to produce sand and gravel; that the alternations here seen are due to *merely temporary alterations of conditions*, as between summer and winter or small oscillations in the extent of the ice.

The section at Blackpool is, perhaps, one of the most favourable to the hypothesis of a mild interglacial epoch. There it is said there are two Boulder clays, separated by a series of sands and gravels.

This series of beds is described in detail with a section by Mr. T. Mellard Reade.[4]

But although it is true there is in this coast section a lower bed

[1] Geology of London, Geol. Surv. Mem. pp. 52, 53.
[2] Q.J.G.S. vol. xlii. pp. 373–4.
[3] *Op. cit.* p. 383.
[4] Q.J.G.S. vol. xxxix. p. 83.

of Boulder clay, succeeded by a series of sands and gravels, which are in turn overlaid by Boulder clay, the general relations of the beds point rather to a partial sorting of materials produced under one set of conditions than to such a great change as that implied by a passage from a glacial to a mild climate.

There is, in the first place, no sign of the denudation of the lower bed of clay before the deposition of the sands and gravels, or of the latter before the deposition of the upper clay.

Secondly, the series of sands and gravels is neither so extensive nor continuous as might be expected on the hypothesis of their interglacial origin.

At one end of the Blackpool section, for example, the only separation between the upper and lower clay is a bed of sand a few inches thick.

Further, the separation into upper and lower Boulder-clay seems merely local. In the first place, Mr. Reade points out, that in a description of the Blackpool section some years previously by Mr. Binny, *no separation* of the clay by sand and gravel is given in one particular part of the section *where there is such a separation now.* He explains this on the supposition, that, as the section is now several yards further inland, the separating beds now visible had thinned out seawards. And he suggests the probability that if the beds could be followed inland, the upper and lower clays would be found to coalesce in a similar way. The probability of this is further indicated by the sections in the neighbourhood.

Thus Mr. Reade describes one where "the Boulder-clay was divided by very persistent seams of sand, though in places these thinned out and the upper and lower beds coalesced and became one without observable division." In other cases, "the shingle is divided by patches of Boulder-clay;" while "irregular sporadic patches of sand occur in the clay."

An artificial section at Sankey Bridge is thus described:—"The Boulder-clay was here penetrated to 100 feet below the surface, the last 20 feet showed 5 feet of sand mixed with coal-dust and 15 feet of clay with bands of gravel. A sand and gravel seam 2 feet thick was passed through about 53 feet from the surface.

It is obvious, I think, that sands and gravel and boulder-clay mixed up in this way cannot be referred to distinct glacial and interglacial epochs. And if we admit a glacial origin for such patches and layers of sand and gravel, we are bound to admit the possibility, if not the probability, of a similar origin for the greater development in the Blackpool section.

The evidence of the fossils of these Lancashire Drift beds is also against the hypothesis of a mild interglacial epoch.

Thus Mr. Mellard Reade after an extensive examination of the Mollusca found in them, concludes that the intercalated sands and gravels are not separable from the boulder clays by their organic remains, *as they clearly ought to be on the hypothesis of a mild interglacial period.* "My object," he writes, "in these preliminary investigations was to ascertain if there were any organic remains

by which the drift-beds might be separated into geological horizons —because, if, as some maintain, two glacial and one inter-glacial period are represented in these beds, there ought to exist, *a priori*, some decided distinction in the Molluscan fauna. I have utterly failed to detect any."[1]

That the limited mass and area of these sands and gravels, and the absence of signs of denudation between them and the Boulder-clay, is decisive evidence against their being the deposits of a mild interglacial epoch, comparable in duration to the glacial period itself, is indicated by a consideration of what would probably take place during such an interval, and by a study of post-glacial sands and gravels.

For, on the melting of the ice, river action would be intensified; vast quantities of morainic matter would be carried down by the swollen streams, and spread out over the boulder-clay of the plains in the form of sand and gravel. At the same time there would be denudation of the boulder-clay in places, and some of these denudation hollows would be filled again with gravel. In places this sand and gravel might reach the sea, and form marine deposits.

But this would not continue for very long: the streams would lose their carrying power; the gravel would no longer be carried to the lower grounds, and they would commence to *cut* their channels through the gravel, and then through the underlying boulder-clay.

This gives a clear idea of the unconformable, denuded junctions we should expect to find between the sands and gravels of an interglacial epoch, and the boulder-clays of preceding and succeeding glacial epochs. And such a course of events is indicated for the close of the glacial epoch, and the incoming of the present mild climate by a study of post-glacial sands and gravels.

In Northumberland, for example, a considerable thickness of such deposits, known as the "Upper Drift Sands and Gravels," are found overlying the boulder-clay. At the junction the latter shows signs of denudation in places, while the overlying beds show at times clear indications of being in part composed of the re-assorted boulder-clay. And since the formation of the upper beds the streams have, in many cases, cut down through sand and gravel and boulder-clay to the rock below.

Ought we not, then, to look for some evidence of a similar course of events in the relations and characters of the beds of the supposed interglacial epoch?

The glacial phenomena of the Vale of Eden, as described by Mr. Goodchild (Q. J. G. S. 1875), point rather to the intermingling and overlapping of the action of ice and water taking place more or less contemporaneously, than to distinct glacial and interglacial periods.

A few sections at the foot of Stainmoor, Mr. Goodchild points out, "show that locally a threefold division of the drift obtains." Yet he adds a little further on, "It is nearly impossible to make out any definite order of succession in the drifts in the lower parts of the

[1] Q.J.G.S. 1874, p. 124.

valley; the few sections seen show plainly enough that masses of sand and gravel pass into, and are interwoven with clay drifts in such a way as to defy any attempt at separation over large areas, although single sections may be indicated which do show a definite sequence."

An inspection of the remarkable series of sections from the cuttings of the Settle and Carlisle Railway given in Mr. Goodchild's paper, showing the intimate interweaving of stratified sands and gravels and laminated clays with till and boulder clay, indicate the utter impossibility of referring the former to a distinct period.

And it is interesting to note that, "towards the mouths of the rivers, the total quantity of clay in the whole accumulation of drift steadily decreases, until very little else than clean sand and gravel is to be found, except in the maritime districts, where the true boulder-clay comes on." For, as the ice descended the valley, the greater would be the amount of aqueous action, and the less that of ice proper.

The glacial deposits of Lincolnshire, and the neighbouring parts, may be cited as apparently favouring the view of interglacial epochs.

Mr. Searles Wood (Q.J.G.S. vol. xxiv. p. 146) divided the series as follows:—

Hessle clay.
Hessle sand and gravel.
Purple clay.
Sands and gravel.
Basement clay (Chalky boulder clay).

He maintained that there was a great break below the Hessle beds, and separated these from the glacial series altogether.

Supporters of the hypothesis of warm interglacial epochs will find evidence for these in the intercalated gravels, and in the supposed breaks in the series.

For, the result of the survey of the district by Mr. Jukes-Browne, leads him to place *another break* between the chalky boulder clay, and the purple clay, although he repudiates the break higher up established by Mr. Wood.

A consideration of the facts brought forward by Mr. Jukes-Browne (Q.J.G.S. vol. xli. p. 114), in his paper on the Boulder clay of Lincolnshire, shows that the series of deposits—even if the above division can be shown to be chronological—does not necessarily indicate climatic changes.

In the first place the chalky clay and the purple clay are not found together in one district; the former occurs on the west of the Wolds, and the latter on the east.

"In East Lincolnshire," says Mr. Jukes-Browne, "there are only three localities where the Brown Boulder-clay comes into contact with the White Boulder-clay." And after describing these junctions, he concludes that the appearances at these places are not against the supposition that the brown clays *pass into* chalky clay.

Other considerations, however—which do not appear to me conclusive—incline him to conclude that the two clays are separable chrono ogically. But, whether this is so or not, the fact remains

that, in the absence of sections, there is here no evidence of an interglacial epoch between the periods of the chalky and purple clays.

Again, glancing at Mr. Jukes-Browne's map, one is inclined to ask, why, on the hypothesis that the formation of the purple clay *was subsequent* to that of the Chalky, none of the former was laid down *on* the latter over all that region west of the chalk Wolds where it occurs; while at the same time it *does* occur further west and north away from the chalky boulder clay? And why, on the other hand, the chalky clay is not found beneath the purple on the east of the Wolds?

As regards the division between the purple and Hessle clays, Mr. Jukes-Browne shows that the sands and gravels separating them graduate into both lower and upper clays; the sand beds containing patches of boulder-clay, and the latter beds of sand in the usual way. He concludes finally that there is no break between the clays.

The presence of *Cyrena fluminalis*, noted by Mr. Wood in the Hessle beds, may be taken as an indication that the climate was ameliorating as the ice gradually disappeared.

Prof. Geikie points to the Interglacial beds of other countries as additional evidence of mild interglacial periods in our Northern hemisphere—he claims it, in fact, from every country yet examined: "In every country where the glacial deposits have been studied, we have clear proof of a mild interglacial period having supervened."[1]

The intercalated beds of Switzerland are of special interest, consisting as they do of seams of lignite from two to five and sometimes even twelve feet thick, and which have been worked for fuel. They are made up of the remains of peat-forming plants, and rest on sand and clay, beneath which is the grund-morâne. Remains of Pines, Oaks, Birches, Larches, etc., occur in these lignites, from which Prof. Heer, has inferred that the climate, at the time of its formation, was the same as that of Switzerland at the present day.

The inference drawn by Prof. Geikie is, "that the great *mer de glace* eventually vanished from the low grounds, and the glaciers shrunk back again into the deep mountain-valleys. The climate grew as mild as it is at present. Oaks, Pines, and other trees overspread the ground, and many large animals became denizens of Switzerland. That this condition of things must have endured for a long time no one can doubt. Nor could the change from the intense glacial climate of the great *mer de glace* have been other than gradual. The glaciers would slowly retire, and many ages would elapse before the condition became such as to induce the growth of Oak-trees. After the genial climate that nourished these trees had lasted for untold centuries, the cold again increased. Slowly the glaciers crept down the valleys. Little by little, year by year, they continued to advance, until at last, escaping from the mountain-valleys, they deployed upon the low grounds. And now, encroaching upon, and eventually occupying the basins of the

[1] Great Ice Age, p. 491.

Alpine lakes, they crept out from these and piled up great end-moraines upon the lower grounds beyond."[1]

Prof. Heer's inference as to climate is, however, somewhat inconclusive. Pine, Oak, Birch, and Larch are doubtless native trees in Switzerland at the present day, but do they not occur up to such heights that they might easily be mingled with the deposits of the present glaciers, especially during some of those minor oscillations to which these are subject? And if those in the lignites are proved to be intercalated with glacial deposits, it may not mean any more than that these temperate forms of vegetation approached the ice of the glacial period as nearly as the same trees approach the ice of to-day. But the evidence that the growth of these trees was succeeded by a glacial period is less satisfactory than that it was preceded by the same.

The lignite is surmounted by sand and gravel upon which are several large alpine erratics. This is certainly suggestive, but hardly sufficient; for, to quote the authors of the Manual of the Geology of India, such "presumed erratics" are the "least certain form" of evidence of glacial action. And in considering such the enormous carrying power of Alpine torrents is perhaps too much lost sight of.

"But," says Prof. Geikie, "the erratic blocks that overlie the lignite are not the only evidence of this second advance of the glaciers. That the ice after retiring from the Jura to the mountain-valleys did again invade the low country had been inferred before the interglacial character of the lignite beds was discovered. It had been known for years that the first ground-moraine and ancient alluvium were overlaid by newer ground-moraines, terminal moraines, and alluvium; the meaning of this having been pointed out by Morlot as far back as 1854."[2]

The facts adduced by M. Morlot, however, can scarcely be considered conclusive evidence of two glacial epochs separated by a prolonged warm interval.

In his paper he speaks of two glacial periods, a *general mighty glaciation*, and a *more limited local glaciation*. The evidence adduced is the presence of "diluvial drift" on boulder-clay.

"*During* the diluvial period," he writes, "the glaciers had entirely disappeared, as has been shown, whilst *after* the diluvial period the glaciers returned, leaving on the diluvial terraces abundant deposits."[3]

M. Morlot mentions examples of this "diluvial drift" *overlaid by erratics*, and *others* of the same drift *lying upon* till; but he brings forward *no case* where it lies *between* glacial beds.

The formation of the loess is attributed to the glacial period. The evidence of the glacial origin of the loess, however, is far from certain, nor is the opinion that it thus originated by any means universal among geologists; so that any argument drawn from its presence on supposed interglacial beds is inconclusive.

[1] Great Ice Age, pp. 405–6.
[2] Edinburgh New Philosophical Journal, 1855, p. 14.
[3] Edin. New Phil. Journ. 1855, p. 18.

Prof. Geikie agrees with M. Morlot as to the relative severity of the two glacial epochs:

"The glaciers of the second period, although of very much larger dimensions than their puny descendants of to-day, yet were themselves but pigmies as compared to the gigantic ice-flows of the first period."

But surely it would be difficult, or even impossible, to distinguish between glacial deposits formed at two distinct epochs of such character separated by a mild interval, but with no distinct memorials of the latter, and a series of deposits formed by ice-sheets and glaciers continuously or intermittently retiring. If the ice, after gradually retiring to a certain point, made a prolonged pause before finally shrinking to its present limits, we might expect to find two *apparently* distinct sets of deposits such as those described, and one of which indicated a much more limited extent of ice. In fact, all the phenomena of these Swiss beds here mentioned are not only possible on the hypothesis of an oscillating and intermittently retiring body of ice, but are exactly such as we should expect on this view.

And Prof. Prestwich does not consider the evidence of these beds —nor indeed the evidence for interglacial periods generally—as conclusive.

"It is asserted," he writes, "that in Europe there were interglacial periods during which the ice disappeared from the surface for great lengths of time. But either the evidence is insufficient or it points to slight temporary effects, except in one case, which is of more importance, and on which the greatest stress is laid, namely, that of Dürnten in Switzerland. There beds of lignite with mammalian remains are intercalated between two glacial deposits. Admitting the fact that the lignite rests on beds of undoubted glacial (ground-moraine) origin, and that the trees grew on the spot where their stumps and remains are found, it by no means follows, as contended, that because these trees are all of species now living in Switzerland, the temperature was that of Switzerland of the present day. *Pinus sylvestris*, *Abies excelsa*, the Yew, the Birch, and the Oak flourish equally in Sweden and far north in Siberia. On the other hand, there is one species of *Pinus* (*P. montana*) which is spread over the mountain country up to heights of 7000 feet, and is rare in the low lands; while one of the Mosses is closely allied to a species now growing on the hills of Lapland. The few species of Mammalia have a distinctly northern facies. *Elephas primigenius*, *E. antiquus*, *Ursus spelæus*, as also *Cervus elaphus*, and *Bos primigenius*, are commonly associated with the Reindeer, Musk, etc., and other Arctic animals of the cold post-glacial times.

Is the return, therefore, of the retreating glacier, supposing the boulder-gravel above the lignites of Dürnten to be due to direct ice-action, to be ascribed to anything more than a comparatively slight temporary change of climate, like those that now for a succession of seasons cause, from time to time, a temporary advance of the glaciers, only more marked? We must allow, of course,

for greater differences and longer intervals of time than now obtain. . . . . But the beds of stratified sand, gravel, and boulders overlying the lignite are more likely to have been the result of glacial torrents than of the direct super-position of the ice which may have again approached, but is not proved to have ever covered the spot."[1]

(*To be concluded in our September Number.*)

II.—Notes on the "Pleistocene Beds" of Gozo.

By J. H. Cooke, F.G.S.

In the year 1874 a letter signed by Messrs. Feilden and Maxwell appeared in the Maltese Journal "Il Barth," in which attention was drawn to a Post-pliocene deposit, said to have been found in the vicinity of Cala Dueira and Il Kala, in Gozo.

A specimen of the deposit, together with a number of shells, that were found in the bed, were forwarded to Prof. Seguenza, who, after having examined them, expressed an opinion that the discovery was one of much importance. From that time to this no further attention appears to have been paid to the matter.

During the latter portion of the summer of 1890 I was engaged in investigating the geology of the Dueira district, and, it was in the course of one of my expeditions that I first discovered evidences of the bed to which Messrs. Maxwell and Feilden had alluded seventeen years ago.

Cala Dueira is a small bay, which is situated at the western extremity of Gozo. Its southern and eastern shores are bounded by mural cliffs of Lower Coralline Limestone,[2] that tower above the level of the sea to a height varying from 150 to 200 feet.

In consequence of a fault, that extends from Monsciar at the head of Wied-el-Arab to Dueira, the eastern boundary of the bay has been let down, and the cliffs are, therefore, no more than 20 feet high in some parts, while towards the west the strata shelve gradually off, and finally disappear in the sea.

At the mouth of the bay there is an outlier of the Lower Coralline Limestone, which is known as the "Fungus" or "General's" rock. It once was apparently a continuation of the now depressed northern boundary. The bay, itself, forms the embouchure of the Dueira valley, the catchment area of which is bounded on either side by a fault of considerable magnitude. That on the northern side extends from the "General's" rock to the northern base of the hill known as Ghar-Ilma. The down-throw that has resulted from this

[1] Q.J.G.S. 1888, pp. 402–3.

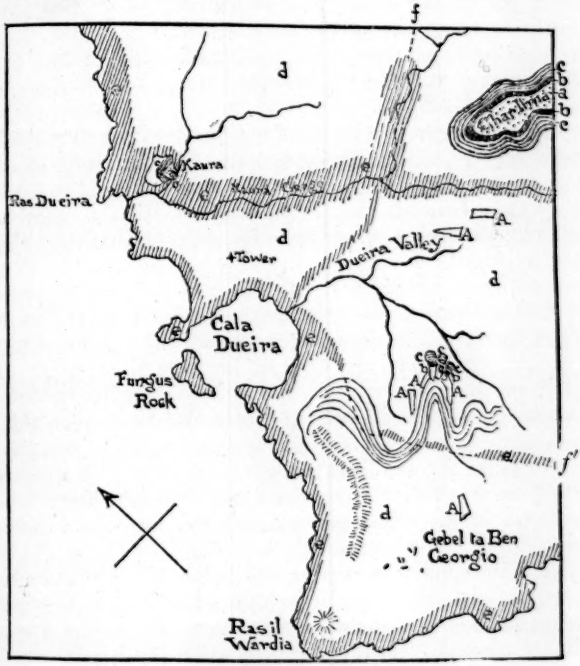
[2] The following table shows the order in which the Maltese formations occur:—

Dr. Murray's Classification.	Capt. Spratt and Dr. Adam's Classification.
I. Upper Coralline Limestone.	I. Upper Coralline Limestone.
II. Green Sands.	II. Sand bed.
III. Clay beds.	III. Marl beds.
IV. Globigerina Limestone.	IV. Freestone.
V. Lower Coralline Limestone.	V. Lower Limestone.

fracture, has depressed the area to the south of it to about 40 feet below the top surface of the Lower Limestone escarpment, that lies exposed along the line of fault.

The fault on the southern side of the bay extends from Dueira *via* Monsciar to Miggiar Scini, and the result of its fracture has been to depress the area to the north of its line.

The accompanying map will show the relative positions of these two faults, and the effect that they have had on the area that lies between them.



Map of a Part of the Island of Gozo, near Malta.

Explanation.

a. Upper Coralline Limestone; *b*. Green Sands; *c*. Marl;
d. Globigerina Limestone; *e*. Lower Limestone;
f. line of fault which has disappeared North of Ghar-Ilma;
f'. line of fault extending to Monsaar, and thence to Miggiar Scini;
A. Pleistocene.

The strata that have thus been let down are much broken and displaced; and, on the southern slope especially, there are several minor faults, all of which wend in a direction that is at right angles to the main fracture.

The beds on both sides of the valley slope at varying angles, in many cases the inclination being as much as 45° and even 60° out of the horizontal. The beds dip inwards, and the result of the synclinal depression, which has thus been formed, is the Dueira valley, the bed of which is represented by the trough of the syncline.

The southern slopes are very uniform in outline; but those on the northern side are divided into a series of smaller valleys or gullies, down which miniature torrents pour their waters for a few occasional hours in the winter time.

The deposits of which the valley is composed do not consist of the Lower Coralline Limestone as is represented in the Geological Map of the Island, which was published by Ducie, Spratt, Adams, and Murray. On the contrary, the Lower Limestone is entirely absent save where it is exposed along the lines of faults that bound the valley; and the deposits consist of all of the beds that are found interstratified between the uppermost and the lowermost of the series. The Globigerina Limestone is the predominant rock; but the blue and yellow clays,[1] and the Greensands,[2] are also to be found *in sitû* along the southern slopes.

Fringing the upper portion of the sides of the valley the Lower Limestone may be seen marking the line of fault, with the Globigerina beds of the undisturbed district above it, and those of the depressed area beneath it. The former relation that existed between the depressed area and its surroundings is therefore distinctly apparent.

I have entered thus into detail because some misapprehension appears to have formerly existed with reference to the geology of this part of the island. Instead of being a valley of erosion similar to the Kaura, the Scini Sclendi, Asel and the Yebbug gorges, it is simply a depressed area, which has been let down by the dislocation of the strata on either side of it. It is also important that these details should be carefully considered; as on their correct representation depends the evidence that must be adduced for proving the the relationship which formerly existed between the Pleistocene deposits found in the valley below the line of fault, and those found on the summit of the slopes above it.

It was while engaged in noting the points of difference between the geology of the district, as it is represented on Ducie's map, and that which actually exists, that I first came across the Pleistocene bed which I am about to describe.

Starting at the head of the valley and proceeding towards its mouth, the Globigerina strata will be observed sloping down the valley side at angles of varying magnitude; and breaking off abruptly towards the lower part, thus forming cliffs of from 10 feet to 15 feet in height. Fringing the slopes that lie beneath these escarpments, there is a bed of white limestone, overlying a bed of yellowish grey loam.

The deposit may be traced for some distance down the valley; but in some places owing to the denuding action of several small streams, that have cut their way, it will be found to occur in patches only.

It is elevated at a height of from 20 to 30 feet above the present bed of the valley; and it extends, East and West for a distance of about thirty yards, and North and South for about fifteen yards.

[1] Bed III. [2] Bed II.

It is lenticular in shape, but breaks off abruptly at the lower side, and an escarpment is thus formed, which shows the maximum thickness of the bed to be about 7 feet, while at the extremities it thins out to 18 inches and a foot.

Its upper surface is extremely hard; and like the surfaces of the surrounding strata, it has been considerably honeycombed and otherwise weather-worn.

The materials of which it is composed are very uniform, both in general appearance and in arrangement. They consist for the most part of fine detrital matter, the product, apparently of the erosive action of the atmosphere on the Upper Coralline, the Greensands and the Globigerina beds.

The deposit is divisible into two well-marked zones, the most persistent features of each of which are the irregularity of its divisional planes and its non-crystalline character.

The top zone consists of an impure, perfectly formed limestone of a whitish colour, and it is usually overlain by a thin, stalagmitic layer of about one inch or less in thickness.

A chemical analysis showed a sample of this bed to consist of about 80 per cent. of carbonate of lime.

In many parts of the bed, minute perforations are noticeable traversing the rock in all directions. They vary considerably both in length and in the diameter of the bore. None of them exceed $\frac{1}{16}$th of an inch in diameter, while many of them are much less.

These capillary tubes often play an important part in determining the direction in which the rock cleaves. They are, however, not persistent throughout the formation, and are more numerous in some parts than in others.

This upper division of the deposit is very fossiliferous; but, owing to the imperfect character of the rock, the Mammalian remains are seldom found in a perfect condition, and even when found entire, they are often so rotten that they fall to pieces under the slightest pressure.

Besides large quantities of land-shells, and mammalian remains, the teeth and vertebratæ of Sharks, Echinoderms, several species of Corals, and other representatives of a marine fauna occur. All of these latter have, however, been derived from the Globigerina Limestone.

The following is a list of the organic remains that I have found in this bed.

MARINE.

Two teeth.	(*Oxyrhina hastilis*).
One tooth.	*Oxyrhina xiphodon*.

(Both of these species are characteristic of beds 2, 3, and 4.)

Flabellum, Zoantharia, and Corallines. One Echinoderm (*Schizaster*, sp.).

LAND SHELLS.*

Helix vermiculata (Müll.) (common).	*Helix virgata* ? Mont.
Helix pisana (Müll.) (common).	*Helix caperata* ? Mont.
Helix striata (Drap.).	*Pomatias melitensis* (Sow.).

* Kindly identified by Mr. E. A. Smith.

FORAMINIFERA.

In the washings of about two pounds of the material, the following species were observed:

Orbulina universa, d'Orb.	*Truncatulina ungeriana*, d'Orb.
Globigerina bulloides.	*Nodosaria* sp.? (broken).
Cristellaria sp.?	*Nodosaria obliquestriata*, Reuss. (broken).
Clavulina cylindrica, Hantken.	Many fragments of others.

Of the land shells the most numerous are those belonging to the Helicidæ.

The specimens are always found in an excellent state of preservation, and in some cases even the original colour of the bands being preserved. Minute specimens of *Helix virgata*? appear present in the greatest abundance; and by washing a portion of the deposit in a sieve, considerable quantities of them may be obtained.

Next in descending order occurs a layer of yellowish grey loamy earth, but the transition between it and the overlying limestone is so gradual, as to render it a matter of considerable difficulty to determine where the one ends and the other begins.

Being of a loose texture the bed easily disintegrates, and thus, by undermining the superincumbent strata, it causes portions of them to break away from the main mass and roll down the slopes.

This loam, like the overlying limestone, abounds in fossil land-shells; but no Mammalian remains appear to be present. Water-worn pebbles of all shapes and sizes are to be found interspersed throughout every part of the bed; but in the loam, though they are more numerous than in the indurated rock above; they are, in the aggregate, much smaller. An examination of a number of these pebbles shows that they have been derived from the three great limestone formations of the islands (Beds I. IV. and V.) in, approximately, the following proportions:—

Bed I. Upper Limestone	10 to 15 per cent.
Bed IV. Globigerina Limestone	50 to 70 ,,
Bed V. Lower Limestone	20 to 30 ,,
Black Limestone	10 to 15 ,,

All of these pebbles are much harder than the rock from which they were derived; and, when broken, they usually present the appearance of a hard external ring of rock of a semi-crystalline character, within which is encased a nucleus of limestone, that is similar in every respect to the rock of the bed from whence the pebble bed had been derived.

This change in the external part of the pebble is apparently due to the infiltration of the limewater, which, after depositing its burden of lime in the interstices of the stone, slowly evaporated, and thus leaves the stone more compact and of a closer texture that when the water was first absorbed in it. The same phenomenon is observable wherever the Limestone beds of the Maltese Series crop out as a surface deposit.

Another remarkable feature of this Pleistocene bed is the extraordinary quantity of Black Limestone pebbles that occur in it.

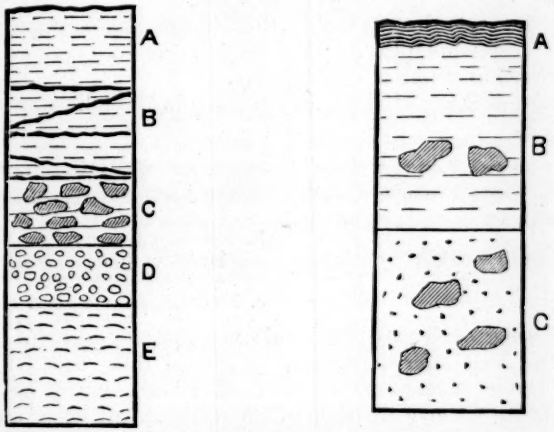
Notwithstanding a diligent search in the district around, I was

unable to discover any traces of a formation partaking of the lithological characteristics of these pebbles, to which they might have been referred.

Proceeding down the valley in a westerly direction, four mounds of blue and yellow clay (the marl beds of Spratt and Adams), are to be seen resting conformably on the southern slope, at an elevation of about 20 feet above the bottom of the valley; and in two cases, the black and yellow sands, that are invariably found to overlie the stratum, are also present.

On the summits of these clay-beds, there occur other patches of the Pleistocene deposit; but unlike those portions that have just been described, these are not *in sitú*, but have been formed, apparently, by the degradation of beds, that were originally deposited higher up the slopes. The materials of which these cappings are composed appear to differ but little from these of the other portions of the bed, save in the total absence of perfect shells, and the comminuted condition in which the fossil bones are found. Such are the principal characteristics of the Pleistocene deposits that are found along the southern slope of the Dueira valley.

The following sketch shows the relative positions of the subdivisions.



A. Greyish, non-crystalline, slightly indurated limestone. Helices and other land-shells occur in abundance; but no Mammalian remains appear to be present.

B. Limestone of a similar character to A, but interstratified with irregular layers of stalagmite. These layers vary from $\frac{1}{4}$ to $\frac{1}{8}$ of an inch in thickness.

C. A layer of boulders and pebbles, all of which have apparently been derived from beds IV. and V. Some of the boulders measure eighteen inches, and two feet in length; and all of them are rounded, and otherwise much water-worn.

D. Loam intermixed with quantities of smaller pebbles. Black limestone pebbles occur in this layer in abundance.

E. A yellowish grey loam, similar in every respect to that which occurs at the base of the other deposits. It abounds with Helices and other land-shells, but no Mammalian remains were found in it.

If, now, the road which winds up the hill-side towards Gebel-ta-Ben-Giorgio, be traversed, the observer will pass from the Globi-

gerina Limestone of the depressed district, across the line of fault marked by the Lower Limestone, to the Globigerina above it.

On the right-hand side of the pathway, that runs through this elevated region, and at a distance of about a quarter of a mile from St. Georgio, another remnant of the deposit may be seen.

Passing down the hill again, and crossing to the northern slopes of the valley, another development of similar accumulations, of even greater extent, will be met with.

These beds, however, present many striking points of dissimilarity to those on the opposite side of the valley. Like the deposits on the southern slope, they extend in an east and west direction, and lie unconformably on the Globigerina Limestone. They occupy a kind of platform on the hill-side, and towards the lower boundary they break off and form an escarpment of from 6 to 8 feet in height. Approaching the valley from the Kaura Gorge, an excellent section of the bed is to be met with about 150 yards down the slope. Its face forms the northern boundary of a field, a large portion of the soil of which has, apparently, been derived from the deposit. This section shows the bed to be made up of a number of layers, each of which differs in a most marked manner from those above and below it.

It will be seen, therefore, that, though agreeing in some respects with the formation on the opposite side of the valley, there are also many important points of dissimilarity.

The most striking of these may be seen in the following table of comparison.

Deposit on the Southern Side.	Deposit on the Northern Side.
a. Boulders are comparatively small, and are interspersed throughout the bed.	a. Boulders are large, and are distributed in well-defined layers.
b. The loam is overlain by a single layer of limestone.	b. The loam is overlain by alternating layers of pebbles, boulders, limestone and stalagmite.
c. Mammalian remains.	c. No Mammalian remains.

The distinct evidences of stratification that are apparent in every part of the beds offer unequivocal proofs of their aqueous origin; and that is a conclusion that is still further borne out by the rounded and otherwise water-worn state of the pebbles that occur so plentifully in them. The finer materials, the pebbles, the shells, and the Mammalian remains have all apparently been collected from the surface of the surrounding country by the agencies of freshets, and inundations of a similar character.

From the evidences afforded by the nature and position of the various portions of the deposits, it would seem as though the surface configuration of the district has undergone changes of a marked description since these beds were formed. Thus the occurrence of patches of the bed both above and below the line of fault would seem to indicate that their deposition must have taken place antecedent to the downthrow to which the now-existing valley owes its origin.

What the immediate causes were that gave rise to the flood-waters,

it is not my purpose here to attempt to determine. That no ordinary floods such as now occasionally occur in the winter months, effected the work of erosion in the Kaura and Dueira districts is a fact that no one would feel inclined to dispute, after seeing the precipitous and rugged sides of the Kaura Gorge, a valley of erosion that lies a few hundred yards to the north of the Dueira valley. The denuded condition of the surface in these localities points to the action of torrential volumes of water; and it was, probably, to the occasional overflow of these from their ordinary channels, combined with the transporting action of the rain on the slopes, that the deposits that form the subject of this article owe their origin.

III.—On *Orthoceratites vaginatus*, Schlotheim.

By Arthur H. Foord, F.G.S.
Royal Dublin Society.

I HAVE lately been favoured by Dr. W. Dames with a separate copy of a communication made by him to the Neues Jahrbuch für Mineralogie, etc.,[1] dated Berlin, 18th December, 1890, in which he points out that in my Catalogue of Fossil Cephalopoda, British Museum (Nat. Hist.) part i. (1888) I have (following Eichwald[2]) wrongly referred a certain "smooth" species of *Endoceras* from Reval in Esthonia, to the *Orthoceratites vaginatus* of v. Schlotheim, —a ribbed species. Dr. Dames states, in the above communication, that he was asked by Dr. Lindström of Stockholm (at the time when the latter was occupied with his edition of the "Fragmenta Silurica") if he could inform him to what species v. Schlotheim had given the name *Orthoceratites vaginatus*. Dr. Dames' reply to this question was inserted by Dr. Lindström in the midst of a very full table of synonymy of *Orthoceras* [*Endoceras*] *vaginatum*,[3] and in that rather obscure situation it escaped my notice. The reply in question was to the effect that the examples of v. Schlotheim's type, sent by Dr. Dames from the Berlin University Museum to Dr. Lindström, were without doubt v. Schlotheim's species.[4] The latter (widely distributed in Esthonia, Sweden, and Oeland[5]) has more or

[1] 1891, Band i. Zweites Heft. Breifl. Mittheil. ii. p. 210.

[2] Leth. Rossica, 1860, vol. i. p. 1243.

[3] Fragmenta Silurica, Angelin and Lindström. 1880, p. 2.

[4] The following is a translation of v. Schlotheim's description of "Orthoceratites vaginatus" (Petrefactenkunde, 1820, p. 53):—"Very beautiful and instructive examples from Reval, in Ueberg. Kalkst., some part still in the matrix, some free, and only about five inches long to a diameter of one inch; besides separate pieces of its remarkable siphuncle. Cf. Knorr, pt. iii. suppl. t. iv*b*. and Breynii opuscula, t. v. f. 2*b*., where this Orthoceratite, together with its elegant, somewhat cylindrical siphuncle is tolerably well portrayed. The length and thickness attained is, it appears, very considerable, whilst the siphuncle belonging to it is found of considerable stoutness. Its relation to the other part of the Orthoceratite is so important that it almost appears as a part of the shell-wall of the latter. It runs, moreover, close to one side of the shell, which in most of the representations of it is not properly indicated, and its protuberances have somewhat of a screw shape; very ornamental, as if elaborately designed. The shell itself is very distinctly oblique, with sharp, somewhat forwardly projecting lines, striated in the direction of the chambers, which latter are bent inwards somewhat stronger towards the siphuncle."

[5] An island in the Baltic, off the east coast of Sweden.

less distinct transverse costæ, and is also covered with conspicuous transverse striæ. On the other hand, the species described by Eichwald under the name *Orthoceras vaginatum* (and by the present writer under that of *Endoceras vaginatum*) has a "smooth" test, numerous chambers, and a remarkably large siphuncle, larger in fact than that of v. Schlotheim's species. Doubtless, continues Dr. Dames, Eichwald was led into this error by v. Schlotheim's citation of a figure in Breyn (Dissertatio physica de Polythalamiis, etc., 1732, p. 36, t. v. ff. 1–4), which apparently represents a smooth *Orthoceras*. Dr. Dames then goes on to say that the specimens called *Orthoceratites vaginatus* by v. Schlotheim himself in the palæontological collection of the Royal Museum of Natural History in Berlin are all typical, well-preserved specimens of *Orthoceras vaginatum*, with ring-like swellings [costæ], and distinct striæ. When, observes Dr. Dames, v. Schlotheim published his "Petrefactenkunde" [1820], he possessed only Esthonian specimens; but later on he received several from Oeland, and as they were identical with the others, he placed them in the same species, and labelled them accordingly. In the Catalogue of Schlotheim's collection, printed in 1832 (p. 32), Oeland is mentioned as the locality, and the quotation from the "Petrefactenkunde" has been added. It therefore appears, says Dr. Dames, that in his reference to Breyn v. Schlotheim has compared a species with *Orthoceras vaginatum* that has no connexion with it. Concluding his remarks, Dr. Dames says that all the specimens in v. Schlotheim's Collection, which he [v. Schlotheim] has named *Orthoceras vaginatum*, belong to the species (recognized as such by all authors except Eichwald and Foord) which is distinguished by its transverse ribs and striæ.

In strict equity v. Schlotheim's name *vaginatus* ought long ago to have been superseded in favour of Hisinger's *trochleare*, because the former was admittedly inadequately described, while the latter was not only described, but figured,[1] in an intelligible manner. It is true that Hisinger had an inkling of the form to which v. Schlotheim had applied the name *Orthoceras vaginatum*, for he inserts that name (though with a note of interrogation after it) under his description of *Orthoceras trochleare*. That v. Schlotheim's description of *Orthoceras vaginatum* was unintelligible even to those who had abundant specimens of it at their command, is clearly proved by the fact that Dr. Lindström was obliged to appeal to the type-specimens in Berlin to ascertain what was the species to which v. Schlotheim had applied that name.

However, in deference to Dr. Lindström's authority, added to the testimony afforded by the specimens at Berlin under the care of Dr. Dames, I cannot but assent to the adoption of Schlotheim's name for the species in question, and I take this opportunity also of tendering my thanks to Dr. Dames for pointing out the error into which I fell with reference to Eichwald's species. On comparing

[1] Lethæa Suecica, 1837, p. 28, Tab. ix. fig. 7. The name *Orthoceras* [*Endoceras*] *trochleare* appears to have been originally bestowed by Dalman. See Hisinger's Anteckningar i Physik och Geognosie, femte häftet, 1831, p. 12, Tab. iv. fig. 3.

a specimen of the latter in the British Museum with the *Endoceras zaddachi* of Schröder,[1] I can see no reason for changing the opinion I formed about it when writing part i. of the Catalogue of Fossil Cephalopoda, viz. that the two species are identical. The *vaginatus* of Eichwald (non Schlotheim) becomes therefore a synonym of *zaddachi*, Schröder, and not vice versa, as in my Catalogue.

IV.—Physical Studies of an Ancient Estuary.[2]

By the Rev. A. Irving, D.Sc., F.G.S.

IT is needless to recapitulate, for the information of the readers of the Geological Magazine, all the incidents which are known to accompany the formation of new land by rivers, or to repeat the descriptions which have been given of the more remarkable instances of them, such as those of the Nile, the Mississippi, the Ganges, the Rhone, the Po, and the Danube. These have been scientifically discussed long ago, by Lyell in his *Principles*. The object of this paper is rather to suggest how a careful collation of such facts as may be learned in connexion with the formation of modern deposits at the mouths of great rivers, or in great estuarine areas (such as the Wash), which receive a number of streams from widely-extended inland catchment-basins, may throw light upon the history of older formations of the same kind, and more especially of those of Tertiary times, during which many important changes were wrought in the physiography of the continent of Europe.

As instances of the work done by rivers in making new land, especially when aided by tidal action, within historic times, one might cite the case of the Po, co-operating with the Alpine rivers which come down from the Venetian Alps, forming a great series of lagoons around the head of the Adriatic Sea, or the advance of the land upon the sea, which has placed the town of Ravenna (a sea-port under Augustus) several miles from the shore; or again, the proved advance of the delta of the Rhone upon the Mediterranean, which has been found to place the Tower of St. Louis a league or so further from the shore in the short space of a single century. But these, and such cases as these, are hardly necessary, when we have here in our own Humber the formation of *Sunk Island* within the course of a few centuries. This island (so-called) is probably well known to Yorkshiremen, but perhaps a comparatively small number of them are aware of its importance, from a geological point of view, as a testimony to the work done by rivers in compensating to some extent the work of degradation and denudation of the higher parts of the country, which is ever in progress, year in year out. This island has been formed by the deposition of sedimentary materials by the rivers Ouse, Trent, and Hull, as their onward flow has been checked, and their transporting

[1] Schrift. der physikal-ökonom. Gesell. zu Königsberg, Jahrg. xxii. Abth. i. p. 93, Taf. iv. ff. 5, *a–d*.

[2] Paper read before the British Association, Section C, at the Leeds Meeting, 1890.

power proportionately lessened, by the counter-force of the tides, rushing up the estuary of the Humber; a process, to the reality of which every 'dredge' employed bears testimony. This process, which the French geologists aptly term 'atterrissement,' is well exemplified in the fact that Sunk Island (a genuine island under Charles II., then just raising its head above the water-line) presented 140 years ago an area of 1500 acres, and was, even then, being brought under cultivation. About the beginning of the present century its acreage was doubled to 3000 actually under cultivation; and in 1854 the survey returns gave between 6 and 7 thousand acres, showing that in the present century the rate of alluvial deposit taking place has greatly increased. The saying of the first Napoleon that Holland naturally belonged to France, because it was made up of the mud of a French river (as he considered the Rhine), is, I dare say, well known.

Prof. Green in his valuable and deservedly popular text-book of "Physical Geology" has discussed the geological principles involved in the formation of a great series of estuarine deposits, with their constant alternation of fresh-water, brackish, chemical and terrestrial formations, their current-bedding, and the wedge-shaped interlacing or interdigitation of beds of different mineral composition. This interdigitation arises for the most part when a series of rivers draining tracts of country of different lithological character, converge to a common estuary; but in cases where the deposits have been laid down, and the process of atterrissement has gone on, in the neighbourhood of the mouth of one great river (with perhaps minor affluents) this characteristic is less marked, and we then find that the *vertical* variation of the rock-character of the series constitutes its principal feature, the successive deposits being traceable over miles of country.

My own studies of the Bagshot Beds of the London Basin have led me to regard them as in the main a mixed series of fluviatile, terrestrial and truly estuarine deposits, laid down under some such conditions in later Eocene time. There is a general vertical sequence traceable through the area, as Prestwich recognized long ago, with variations laterally of percentage of lithological constituents and homogeneity of structure, of the several beds. By the term 'estuarine' I mean to indicate those deposits which are laid down in the open area into which the river flows, and to which the ocean-tides have access; a connotation supported both by etymology and the usage of earlier writers on geology. Such deposits are thus distinguished in a real sense from those which are deltaic or fluviatile. A parallel case might be cited in the still older Eocene series known as the Lignitiferous Series of the Soisonnais; a series of numerous alternations of sands, clays, and beds of lignite, while the fossils met with indicate a special régime; shells of mollusca essentially *marine* (as *Ostrea* and *Pectunculus*) occurring along with others (such as *Melania*, *Melanopsis*, *Neritina*, *Cerithium*) which are known to prefer the mouths of great rivers for their habitat, while such strictly fresh-

water shells as *Paludina* are also found.[1] Now the Bagshot Series do not present us with quite such a complex of alternating conditions as is recorded in the Lignitiferous Series of the Soisonnais: they rather mark a progressive series of changes from strictly fluviatile conditions to those which prevail in a marine estuary. The *physical*, the *stratigraphical*, and the *palæontological* lines of evidence all agree in testifying to this fact; a fact that can only be satisfactorily explained by the phenomenon of a slow subsidence with intermittent pauses of long duration, during which the relative levels of sea and land remained pretty stationary.[2]

The starting point in the investigation of the physical history of the London Bagshots was the discovery of the *organic origin of the green colouring matter* which is so commonly found in these sands at certain horizons. Various salts of iron are formed in this way, which ultimately break up by exposure to atmospheric oxygen; their non-metallic constituents are resolved into carbonic acid and water, while the iron is precipitated as limonitic mud. So completely was this proved to be a true process of nature, that I was able to make it the basis of a process for the purification of water contaminated by dissolved vegetable matter, for which a patent was granted me in the year 1885. Not only limonite but iron pyrites is formed, the latter by the sulphur, furnished by the decay of vegetable albuminous matter, attacking iron. Both these minerals are of very common occurrence in the Lower and Middle Bagshot strata; and both serve as cementing material for *nodules* which we frequently meet with both in the sands and in the more sandy varieties of clay. Even *lignite* in a fragmentary state is not uncommon, reminding us of the great brown-coal deposits of the Continent of about the same age.

The *limonite* is deposited in large and small concretionary masses, and sometimes in continuous layers, resembling in every way that which is dredged up from the Swedish and Canadian lakes, to be utilized as iron-ore; the excellent quality of Swedish iron being largely due to the fact that a pure chemical precipitate of iron oxide is thus made the basis of its manufacture. As there the conditions of primeval forest prevail over a large proportion of that Archæan region, and the decay of forest litter furnishes the acid solvents for the leaching-out of iron from the rocks, the iron being precipitated as the water undergoes oxygenation in the shallow lakes; so here in this ancient Eocene delta vegetation has by its decay furnished the solvents; the same cycle of change, and the same laws of nature have been in operation. As solvents, too, of *silica* in the presence of strong bases, these organic acids may have played their part in

[1] See Prof. Stanislas Meunier, "Les Causes Actuelles en Géologie," pp. 269, 270.

[2] I may be allowed to refer to a sketch in a popular form, of what I conceive to have been the outline of the history of the Thames Basin, as I put it forward in a lecture last winter, a summary of which appeared in "Science Gossip" for May and June, 1891. I should like to draw particular attention to the many points of similarity between the conclusions I have arrived at as to the Tertiary history of this part of England, and those arrived at by Prof. Sacco of Turin, as to the Po Basin. (See "Bull. de la Soc. Belge de Géologie, etc., tome iv. 1890.)

the formation of the *glauconite* (essentially a mixture of hydrous silicates of potash and the oxides of iron[1]), which gives such a marked character to the green earthy sands of the Middle Group, and helps to testify to their lagoon-origin. [The minute flakes of glassy silica described in previous papers, as well as the secondary crystals on the quartz grains, are, I believe, authigenous products; while the *abraded* scales of mica, so common in the sands associated with the clays of the formation, are in all probability allothigenous material, testifying to the erosion and denudation in later Eocene time of the crystalline rocks of the mountain-system to the west, which furnished the head-waters of the great Eocene river.]

"*False-bedding*," both on the larger scale and on that smaller scale known as "current-bedding" or "oblique lamination" is a phenomenon of extremely common occurrence in the sandy beds of both the Lower and Middle Group, testifying to the variations in strength and direction of the currents which laid the deposits down in their present position. Between the sand-beds (often current-bedded) there frequently occur, both in the Middle and Lower Group, thin seams, sometimes mere films, of pure *pipe-clay*, telling us of alternation of quiet conditions and the settling-down in still waters of the fine argillaceous materials, which, as every geologist knows, are capable of suspension in water for a considerable length of time. This alternation of conditions is so frequently and so strongly marked in the *interlaminated arrangement of clay and sand* in certain beds of the Middle Group, that, as a physical fact, it was one of the first among those, with which my earlier observations of these beds made me familiar, to suggest to my mind a deltaic origin for them. Some of the older geologists were startled three or four years ago, at my suggestion that the pipe-clay might be, in part at least, derived from the Chalk strata, which must have been exposed to subaërial erosion over considerable areas within the catchment-basin from which the waters were concentrated to the area in question. I was able to establish the probability of this by a very simple piece of laboratory work. A small quantity of the marly material of the Lower Chalk was pulverized and treated with very dilute acetic acid. The material was washed and re-washed with this, until no further escape of carbonic acid could be detected. The insoluble argillaceous residue settled down after suspension in water, to form a thin film of pure clay, similar in every way to the filmy deposits of pipe-clay which we meet with in the Bagshot Sands. What a feeble organic acid could do in that case might easily be done in the ordinary processes of nature, with sufficient time and the conditions prevailing in a deltaic area, by the action of the *humus acids*, which decaying vegetation furnishes. The facts here stated seem, I think, to justify my refusal to accept the presence of either current-bedding, or pipe-clay films, or of both together, as infallible tests of horizons, as has been persistently urged by one or two workers in the Bagshot Series. The fact

[1] See Naumann-Zirkel: "Elemente der Mineralogie;" Leipzig (Engelmann), 1885. Also, Justus Roth's "Chem. und Allgem. Geol." p. 559.

established by more extended observations is that a pure massive clay deposit is found only in the Middle beds, and that the conditions favourable to its deposit were feebly anticipated in the upper horizons of the older fluviatile sands, and were feebly repeated in places in the earlier stages of deposition of the younger Upper Sands.

In the Quart. Journ. of the Geol. Soc. for August, 1887, I have given many of the results of my studies in the Bagshots, not the least interesting being the discovery of Freshwater Diatoms in some of these beds. In a later number of the same Journal (May, 1888) I have pointed out that the prevalent rounded form of the grains of sand in the greenest beds points to their having suffered a vast amount of æolian attrition, in the shifting of sand-dunes by the wind, before they were deposited in the lagoons, in the same manner as is now going on on some parts of the shores of the Baltic. To this kind of evidence we may now add the frequent occurrence of thin beds and laminæ of very pure clay in the very heart of these green-earth beds, where they are most fully developed, telling us of the still waters of the deeper portions of these lagoons, never ruffled by the wildest storms, too deep as yet to allow of the growth of the vegetation which lined their margins and covered the intervening swamps. We can even in some cases, with the data now to hand, measure the rate of the thinning out of the green-sand series as well as of the Lower quartz-sands, and thus at the same time approximately map the original outlines of some of the lagoons, as well as measure roughly the amount of local and contemporaneous subsidence which the underlying clays suffered.[1]

In the former paper referred to (1887) I ventured to suggest a natural classification of the beds of the Bagshot Series of the London Basin into—

a). An *Upper Marine-estuarine Series*;

b). A *Lower Fresh-water Series* of riverine, delta, and lagoon origin; in the place of the more empirical division into Upper, Middle and Lower, which is of no importance except for cartography, and even there is often as misleading as not.

The fact that occasional fossiliferous bands or zones are met with, and that some of the forms bespeak a marine habitat, no more proves the marine origin of this complex of sands, green-earths, and clays than the marine shells found driven some miles inland by a great south-westerly gale in the Rhone Delta[2] prove the marine origin of its beds; it might as well be argued that the Coal-measures were a "marine series" because of the occurrence at certain horizons of the well-known "mussel-band," or even of occasional lines of real marine shells. Colonies of creatures of a more or less marine character doubtless established themselves here and there in the more saline parts of the lagoons, and in the Bagshot beds these are preserved usually as casts in the cemented sand; but in the rare cases in which actual shell-structures have been preserved, it is certainly

[1] Perhaps the Norfolk Broads present some analogy to the conditions which prevailed in this old Tamisian estuary in later Eocene time.

[2] Described by Lyell in the "Principles."

true, as far as my observations have gone, that they are much "broken, worn, and even comminuted:" for one even tolerably perfect shell there are hundreds of fragments of shelly *débris*, speaking to us eloquently enough of their drifting inland from time to time from the outer marine area. Some of the little Oysters *O. flabellula*) found for example at Yateley, were so much abraded that it was only after comparing them with many forms in the Jermyn Street Museum (with Mr. Newton's kind help) that I could convince myself of their specific identity.

The Upper Sands.

Messrs. Gardner, Keeping, and Monckton, in a recent paper,[1] state that "the beds [of the Upper Bagshot], and what can still be recognized of their fauna, are such as might have been formed in an open sea of considerable depth." But this statement amounts to very little, because, so far as the fauna is concerned, there is nothing inconsistent with the view that the molluscan forms which they have tabulated might just as well have been left by creatures which inhabited a shallow salt-water estuary. This will, I think, be clear to any one who will take the trouble to work through their list with the aid of such a reliable work as Woodward's "Manual of the Mollusca." That they are right in correlating the Upper Sands of the London Basin with the Barton of the Hampshire Basin is very probable; indeed, my own studies, which have proceeded rather on physical and stratigraphical lines, have led me to the same conclusion as that at which they have arrived; namely, that the break postulated at the base of the Upper Sands is in reality very inconsiderable. So far from requiring any great length of time to convert this Eocene delta with its swamps and lagoons into a tidal arm of the sea, we know that such changes may take place without any great draft on the bank of geologic time, seeing that within a 1000 or 1500 years the swamps and lagoons of the Yssel, through which, Tacitus tells us, Germanicus led his forces against the immortal Hermann, have all disappeared beneath the waters of the Zuyder Zee; while several hundreds of square miles of Holland at the present day are only preserved from permanent submergence by artificial barriers. Of the comparative rapidity of this later subsidence of this Eocene area we have evidence in the strata themselves. It is only by such an encroachment of the sea that we can give a rational account of the Bagshot pebble-beds, which recent researches have established as an important fact of Bagshot stratigraphy. These beds vary in thickness from a few inches to five feet or more. They are composed of well-rolled flint-pebbles derived entirely from the Chalk strata, which must have enclosed this Eocene area of deposition on the south and the north-west. It may be assumed that no rivers, that could have drained this Chalk area in Eocene times, even when all allowance is made for its *quondam* extension, could have manufactured such vast quantities of rounded pebbles out of angular flint fragments as we find sealed

[1] See Q.J.G.S. vol. xliv. p. 616, 1888.

up in the Bagshot Beds over a large extent of country in the Basin of the Thames. We must look, therefore, to the action of a tidal surf as the only efficient agency. We know by direct observation how the hardest rock-fragments are converted into smooth pebbles by grinding along a shore-line under the influence of tides and storms; and we have plenty of instances of the way in which such pebbles are piled up into 'Chesil-banks' along the seaward margins of deltas. Even the form of the pebbles themselves testifies to this as their true history; the discoid form which they frequently acquire (as may be seen on the coast of South Devon, at Weybourn on the Norfolk coast, or on the 'Chesil-bank' at Portland), being reproduced in the flint-pebbles of our Bagshot Beds. In one of the most massive pebble-beds the pebbles are so commonly of a smooth discoidal shape that I have seen numerous heaps of these picked out from the pebbles that have been used in making a new road.[1] Now when we recollect that the facts cited tell us of shore-action upon a Chalk shore-line, there is no difficulty in conceiving how the waters of the Eocene sea may have pursued their destructive work upon the Chalk of the east of England, as it extended in all probability at that time much further to the north and east.

When the last great stage of subsidence of the area set in, the pebbly shingle accumulated in the way here indicated would be driven inland, strewn over the original delta, and swept in places along its margin into such shelves or banks of shingle as we actually find along the northern margin, as far as we have been able to trace it. Nor do we suppose that there was anything of a cataclysmic nature in this; for, though the most general distribution of pebbles is at the base of the Upper Sands, this change did not come on all at once, as we know from the fact that other and less widely distributed pebbly deposits occur mixed up with the green earthy sands of an earlier stage at their uppermost horizon. Again, of the 52 species of Mollusca given by the authors quoted above as found in the Upper Sands some deduction must be made on account of the very imperfect way in which they have been preserved (merely casts for the most part in sand cemented together with peroxide of iron); and of the residuum, as many as ten are represented by their *genera*, and two at least by their *species* in the preceding Middle Group. These facts seem to warn us against postulating any very considerable temporal break between the two series. That the most massive banks of pebbles are found towards the western portion of the area would seem to follow as a natural result of the narrowing of the area towards the west, and consequently greater driving power of the tides, as their velocity increased with the narrowing of the area over which they were driven.

It was this subsidence of the area into a marine estuary which no doubt furnished the sandy and muddy bottom on which most of its fauna passed their existence; nor do I think that there is any real

[1] Pebbles of this form are frequently used for rough paving-work, in this part of the country, just as the great market-place of Nottingham is paved with Bunter pebbles collected from the drift of the Trent valley. The whole of the streets of Norwich were thus formerly paved with pebbles from the Boulder-clay and Drift.

scientific basis for the hypothesis that the Upper Sands were once as rich in fossils as the more clayey Barton beds of Hampshire. The hypothesis of 'decalcification' may be run too hard. We must be allowed to insist upon proof of the fact being given in any case before admitting it as an explanation. In the case before us we can understand perfectly well how atmospheric waters, charged with the humus acids furnished by the decay of forest-litter in this area of ancient forest-land have first taken up iron in the sands to form salts of the protoxide, and then, on coming into contact with the shells embedded in the sands, have by a simple chemical reaction or interchange of acids and bases substituted for the carbonate of lime carbonate of iron, to be subsequently broken up by the oxidation of the iron into the peroxide, which gives the pseudomorphic casts of the original shells.[1] I have not, after much study of the question, the slightest doubt that this is the true history of these 'irony casts'; and I think that the direct action of merely carbonated atmospheric waters has had very little to do with their production.

In connexion with these Upper Sands space prevents me from adding more than to draw attention to the fact that there are I believe signs in places of their beds having been formed by the planing down of the sand-dunes of the earlier deltaic stage; the materials having been stored up to a large extent during the long period occupied by that stage, and only needing redistribution by tidal action to give us in part the present beds of the Upper Sands.

The *time* represented by these few hundred feet of strata, as measured by the maximum development of their continental equivalents, is seen to be very great; and the study of their physical history tells us that such a lengthened period of time was required for their formation. The two series of deltaic clay deposits (entirely unfossiliferous), with their intervening and intimately associated green earths, probably occupied by far the greater portion of it. Compared with the necessarily slow accumulation of materials which the physical study of these reveals to us, the deposition of the fluviatile sands which preceded them and of the marine-estuarine sands which succeeded them was probably what might almost be called a rapid process.

V.—On the British Earthquakes of 1889.[1]

By Charles Davison, M.A.,
Mathematical Master at King Edward's High School, Birmingham.

(*Continued from page* 316.)

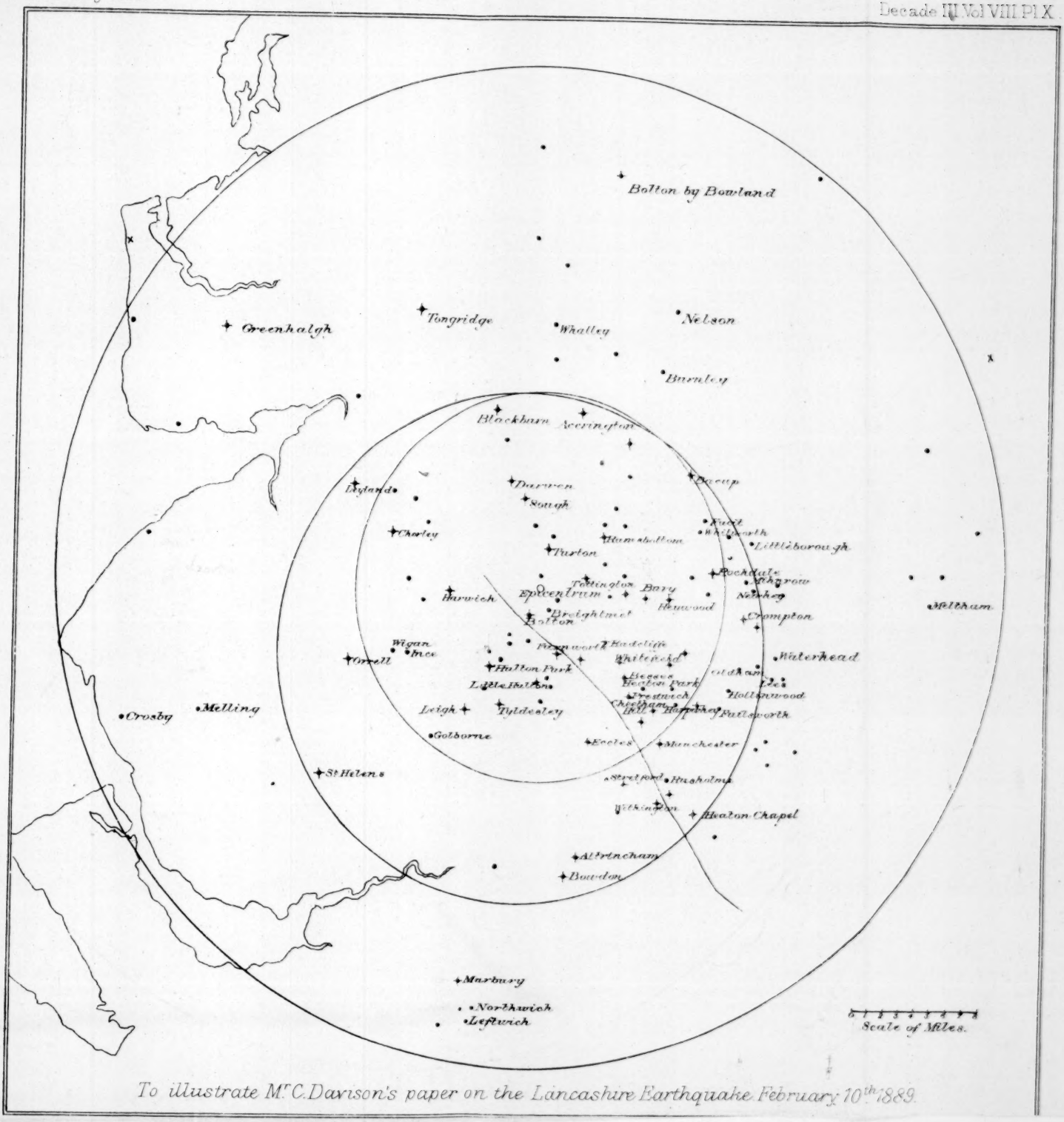
(PLATE X.[2])

3. Ben Nevis Earthquake: May 22, 1889.

Time of occurrence, 13 h. 58 m.; Intensity, about IV. Epicentrum, probably not far from Ben Nevis.

[1] There is nothing new in this. Dr. Alexis A. Julien explained in this way the formation of the irony casts in the "Northampton Sands," which are well known. See "Amer. Assoc. Adv. Sci." for 1879.

[2] Plate X. illustrates the area disturbed by the Lancashire Earthquake of February 10th, 1889, described in the Geological Magazine for July, 1891, pp. 306–316, forming part 2 of this communication.



To illustrate Mr C. Davison's paper on the Lancashire Earthquake February 10th 1889.

I am indebted to Mr. R. T. Omond, Director of the Ben Nevis Observatory, for the only information I have been able to obtain with reference to this earthquake. "It was," he says, "sufficiently strong to make part of the wooden roof creak, but was, as far as I know, not noticed in any other part of the country." The few inquiries that I have been able to make confirm this remark, and I think we may therefore conclude that the epicentrum cannot have been very distant from Ben Nevis. The great fault, which crosses Scotland from Inverness in a south-westerly direction, passes at the surface within a short distance from Ben Nevis; and being, in other parts of its course, closely associated with recent earthquakes, may possibly, by a slip, have given rise to the Ben Nevis shock.

In connexion with this earthquake may be mentioned a slight shock felt on June 19, 1889, at 7h. 40m., at Invergarry, a place 26 miles N.E. of Ben Nevis, and also close to the same great line of fault. Mr. John Grant, of Invergarry, was kind enough to send me a note of this shock, and also a list of several others felt between Jan. 1, 1888, and Jan. 19, 1890. I have followed the rule laid down by the Swiss Seismological Commission, of not treating as undoubted earthquakes those which rest on the authority of one observer only; but, at the same time, I think it is evident, from the opportunities which Mr. Grant has had for these observations, that this is a somewhat exceptional case. I add here his list of the earthquakes felt at Invergarry during the year 1888, as it has an obvious bearing on the seismic history of the district:

1888.

Jan. 5, 5h. 30m., four vibrations, strong enough to shake lamps, dishes, etc. (Intensity IV.)

Feb. 2, 5h. 5m., one vibration, like the passing of a heavy carriage.[1]

Feb. 29, 20h. 10m., one vibration, like a carriage passing.

March 1, 9h. 15m., the same.

April 4, 9h. and 11h., like a light carriage passing.

May 20, 18h. 10m., the same.

July 3, 14h. 30m., the same.

Oct. 22, 13h. 25m., the same.

4. Kintyre Earthquake: July 15, 1889.

Time of occurrence, about 18h.; Intensity, V. Epicentrum, about $3\frac{1}{2}$ miles S.E. of Clachan.

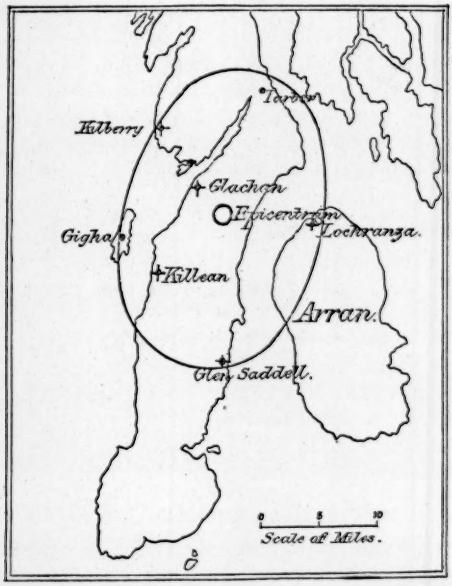
Disturbed area.—I have only succeeded in obtaining records of this shock from eight places; but the information received from these and other places is sufficient to enable the boundary to be drawn with a fair approach to accuracy. Thus, the shock was not felt at Campbeltown or Southend, nor on the west side of the ridge of Gigha Island. In Arran, the Rev. J. Johnstone informs me, it "was felt from Pionmill right by the Crawhill and Lochranza, passing through the glen that enters Lochranza from Sannox."

[1] This earthquake was felt over the greater part of northern Scotland.

The disturbed area is thus roughly elliptical; its longer axis, in a direction about N. 30° E. and S. 30° W., being about 25 miles long, and the shorter axis about 18 miles. The whole area disturbed, including that covered by the sea, is about 350 square miles. The boundary of the disturbed area corresponds to an isoseismal line of intensity IV.

Nature of the Shock.—From the few records I possess on this point, it would seem that the shock consisted of only one vibration; no tremulous motion, either before or after the shock, being noticed at any place.

Duration.—The estimates of the duration are fairly concordant. It is stated to have been not more than two to three seconds at Glen Saddell; several seconds at Kilberry; two seconds, or perhaps more, at Lochranza; and not more than four or five seconds at Gigha. But, as there was only one vibration noticed, it is probable that these estimates include also the duration of the sound that accompanied the shock.



Kintyre Earthquake: July 15.1889.

Intensity.—At Lochranza, the intensity must have been V. or nearly so. It was probably greater than IV. at Killean; and IV. at Glen Saddell, Kilberry, Clachan, and Gigha.

Sound-Phenomena.—So far as I can learn, the sound-area was approximately co-extensive with the disturbed area considered as bounded, as above stated, by an isoseismal of intensity IV. From Ardpatrick and Tarbert I have no particulars beyond the fact that

the shock was felt at those places. But, at the other six places marked on the map, the characteristic earthquake-sounds were heard. They were compared to the movement of heavy articles of furniture overhead (Glen Saddell and Killean), the passage of heavy vehicles (Kilberry and Lochranza), a strong blast of wind up the chimney (Gigha), and a cartload of stones being suddenly emptied (Gigha). The sound is said to have accompanied the shock at Kilberry, and to have preceded it at Glen Saddell and Lochranza.

Position of the Epicentrum and Geological Relations.—The centre of the disturbed area is about 3½ miles S.E. of Clachan. That the earthquake can have had no connexion with the great southern boundary fault of the Highlands is evident from the distance of the epicentrum from the continuation of the line of this fault. Prof. C. Lapworth, F.R.S., has, however, been good enough to give me the following note on the possible geological relations of this earthquake.

"The geological structure of this district shows that between Loch Fyne and its prolongation, Loch Killisport, there is a band of slaty material more or less unaltered. A corresponding band occurs on the fringe of the Highland district, running from Stonehaven to Dunoon and Rothesay. Between these two well-marked lines of slate, lies a great area of gneiss. The relation of the gneissic rocks to the slaty rocks is disputed; by some it is suggested that the gneisses rise in an anticlinal form from below the schists; by others, that the gneisses lie on a synclinal formed of the slates. The apparent dips of the metamorphic strata make the latter interpretation the simpler and more probable one to geologists accustomed to lowland areas. If we recollect, however, that the Highlands are actually a denuded mountain complex, it becomes far more probable that this apparent synclinal is actually a fan-structure or inverted anticlinal, as suggested in my paper on "The Secret of the Highlands."[1] If this is the case, the slipping and movements caused by lateral pressure will take most effect along the two planes of contrary motion running midway between the crest of the main fold and its bounding synclines. Curiously enough, the line of direction of the axis of the disturbed area coincides precisely with the theoretical position of the southern zone of contrary movement, on the assumption that the gneisses form an inverted anticlinal."

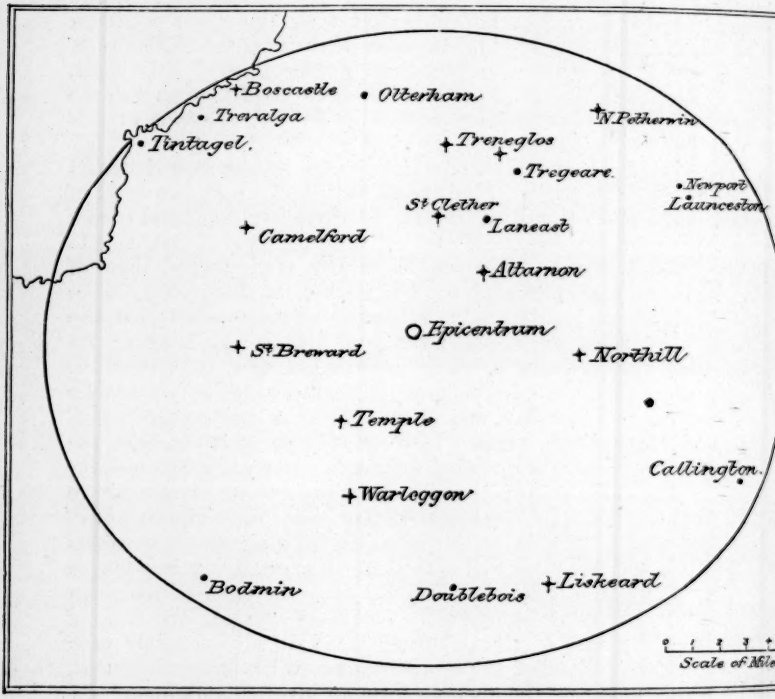
Authorities.—The only published account of the earthquake that I have met with is contained in the "Oban Times" for July 20; and I am indebted to the courtesy of the Editor of this paper for searching his files and sending me the extract referred to. For the greater part of the information on which the above account is founded, I have to thank the following gentlemen: the Revs. J. Johnstone (Lochranza, Arran), D. N. Macdonald (Killean), J. F. McKenzie (Gigha), and H. W. Strang (Campbeltown); Mr. R. A. Cavana (Gigha); and especially Mr. J. N. Macleod of Kintarbert and Saddell, without whose aid the account of this earthquake would have been much more imperfect than it is.

[1] Geol. Mag. Dec. II. Vol. X. pp. 120–8, 193–7, 337–44 (1883).

5. East Cornwall Earthquake: Oct. 7, 1889.

Time of occurrence, about 13h. 45m.; Intensity, IV. Epicentrum, about $2\frac{3}{4}$ miles S.W. of Altarnon.

Disturbed Area.—All the places, 24 in number, at which the earthquake is recorded as having been felt, are included within an area which is roughly elliptical in form. The larger axis, which runs nearly east and west, is about 25 miles in length, the shorter axis about 20 miles, and the whole area disturbed about 400 square miles. The curve bounding this area is an isoseismal of intensity IV.



E. Cornwall Earthquake : Oct 7 1889.

Nature of the Shock.—The accounts of the shock, though few in number, are sufficient to indicate roughly the way in which the nature of the shock varied throughout the disturbed area. We may divide the observations into two groups. In the first we have:

Altarnon: a distinct rumbling was heard, as if the chimney were on fire or a heavy waggon passing up the road; very little if any perceptible vibration.

North Hill: a sound heard as though something had struck the wall of the house, and "then the sound seemed to vibrate at the back."

St. Clether: like a distant peal of thunder or the passing of a very heavy loaded waggon; no tremors perceived.

Temple: like the rumbling of thunder for a few moments, followed by a tremulous motion.

Trenegloss: a loud rumbling noise like thunder; no tremulous motion perceived.

With the exception of Laneast, from which I have no detailed account, these five places are nearer to the spot indicated as the epicentrum than any of the others from which records have been received. From this point, Altarnon is distant $2\frac{3}{4}$ miles, North Hill 5, St. Clether 4, Temple 4, and Trenegloss $6\frac{1}{4}$ miles.

The second group includes places in the neighbourhood of the boundary of the disturbed area:

Bodmin: as if some person were walking with a heavy tread three or four steps overhead.

Boscastle: two distinct shocks are said to have been felt.

Liskeard: (1) as if a heavy substance were thrown violently on the floor of the adjoining room and also against the partition dividing the two rooms, tremulous movements before the shock; (2) one sudden crash like an explosion, no tremulous motion perceived.

North Petherwin: a slight vibration like that produced in a house by the passage of a heavy waggon.

St. Breward: like that produced by a cart passing along the road at the back of the house.

Warleggan: as if something very heavy had fallen in the house with great violence, followed by a tremulous motion.

From these accounts, we may conclude that, in the neighbourhood of the epicentrum, the sound-vibrations were most noticeable, but that these died out more rapidly towards the boundary of the disturbed area than the vibrations of longer period, and near the boundary the shock was felt as one or several thuds, or vibrations of much larger amplitude than those which preceded and followed them.

Duration.—The duration of the shock is variously estimated at from two to about twenty seconds. Thus, at Liskeard, according to one account, it is said to have been more than two seconds, according to another about fifteen seconds; a tremulous movement before the principal vibration being included in the latter estimate. Other observations give about 2 seconds at North Petherwin, about 3 at St. Clether, 3 or 4 at Temple, 4 or 5 at Warleggan, 10 to 20 at Trenegloss, and 12 to 20 at St. Breward.

Intensity.—Throughout the disturbed area, the intensity seems to have been remarkably uniform, indicating probably a great depth of the seismic focus. According to the Rossi-Forel scale, the intensity was IV. at the following places: Bodmin, Camelford, Liskeard, Newport (near Launceston), St. Breward, Temple, Trenegloss, Tresmere, and Trevalga. It may have been slightly greater than IV., though probably not as great as V., at Altarnon, St. Clether, and Warleggan: and perhaps slightly less than IV. at North Hill.

Sound-Phenomena.—The sounds accompanying the earthquake have been already alluded to: they form perhaps its most noteworthy features. They seem to have been of the usual description, being compared to thunder, to heavy waggons passing rapidly along adjoining roads, and to the roaring of a chimney on fire. At the following places the sound is said to have accompanied the shock: Camelford, St. Breward, St. Clether, Temple and Trenegloss. It preceded the shock at North Petherwin, and perhaps also at North Hill and Tresmere. At Warleggan, the rumbling sound was heard just after the shock, "as if a waggon had run away down the hill outside our house: it increased in sound and then appeared to me like an express train going through a station. . . . . The rumbling ended quite abruptly." At Liskeard, it preceded the shock; but another correspondent at the same place informs me that it was heard both before and after the shock, both times very low, but rather louder after than before.

The earthquake-sounds were heard at all places from which I have detailed accounts. The sound area and the disturbed area may therefore have been coextensive, or nearly so. Further, since the sounds were the most notable part of the phenomenon near the epicentrum, and at a place like Liskeard near the boundary of the disturbed area were only heard by a few persons, we may conclude that the intensity of the sound diminished more rapidly than that of the shock as the distance from the epicentrum increases; and, consequently, that the sound-focus was nearer to the surface than the rest of the seismic focus.

Position of the Epicentrum and Geological Relations.—The epicentrum of the earthquake is about $2\frac{3}{4}$ miles S.W. of Altarnon, *i.e.* not far from the centre of the great granite boss which occupies so large a part of East Cornwall. It is also noteworthy that the duration of the shock was in some parts considerable, as much as 10 or 12 seconds, arguing probably a larger seismic focus than in any of the previous cases; further, that the longer axis of the disturbed area runs east and west, *i.e.* parallel to the direction of folding of the district. Though we may not at present be in a position to assign a definite origin to this earthquake, it seems at least probable that it had some connexion with the geological structure of the district, and that the forces which have combined in producing that structure have not yet ceased to act.

Authorities.—"St. Austell Weekly News," Oct. 12; "West Briton and Cornwall Advertiser" (Truro), Oct. 10; "Western Morning News" (Plymouth), Oct. 8.

The earthquake was but slightly noticed in the local press, and nearly all that is of value in the preceding account I owe to the kindness of the following ladies and gentlemen: the Revs. R. H. Boles (St. Breward), C. Bridgewater (St. Tudy), J. R. Browne (Bodmin and Temple), W. Jago (Bodmin), A. H. Malan (Altarnon), C. Olive (Warleggan), J. Partridge (St. Clether), T. B. Trentham (North Petherwin), Canon Vautier (St. Mabyn), T. Walters (Boyton), and T. Willing (North Hill); Mr. J. C. Chapman (Trenegloss),

Mrs. L. Davy (Tresmere), Miss F. E. Jenkin (Liskeard), Mr. W. E. Parsons (St. Breward), and Miss L. Thorne (Liskeard).

Doubtful Earthquakes.

1. *Invergarry*, June 19, 1889, 7h. 40m. (see p. 365).

2. *Little Rhondda Valley* (South Wales), June 22, 1889, about 22h. 30m.; intensity, V.

A shock, supposed to be that of an earthquake, was felt at this date in and near the Little Rhondda Valley. The area disturbed by it was very small, probably not more than a few miles in its greatest diameter. It was felt at Llwynypia, Pontygwaith, Tylorstown, Watts Town, Ynishir and Ystrad.

The disturbance, which lasted a second or two, consisted of one vibration, and at Ynishir is described as having been like the shock of a blasting explosion, but much stronger. It was accompanied by a deep rumbling noise, like distant thunder, at Llwynypia, Pontygwaith, and Watts Town. The intensity was IV. at Pontygwaith, but cannot have been less than V. at Llwynypia and Ynishir. The shock was felt by workmen underground in the Ynishir Steam Colliery, and in one or two other collieries in the adjoining district.

This is all the evidence I have been able to obtain, and I do not think it is sufficient to put beyond doubt the seismic origin of the shock. For so small a disturbed area, the intensity is unusually great, arguing a very small depth for the centre of disturbance; and, besides this, the mining operations of the district are being carried on so rapidly and extensively that, from time to time, considerable masses subside, occasionally, it is said, causing tremors very like those of an earthquake.

Authorities.—"Nature," vol. 40, p. 208; "South Wales Daily News" (Cardiff), June 24, 1889. For other information contained in the above account, I beg to thank Mr. W. Galloway, Mr. J. J. Thomas, of Ynishir, and Mr. R. R. Hood, of Gilfach.

3. *Lyme Regis*, July 5, 1889, between 23h. and 23h. 15m.

Noises were heard at intervals between the times stated. They "consisted of a distant rumble which grew nearer till at last the windows of the houses rattled and in some cases distinct vibrations of the houses were felt." They were probably not caused by the firing of guns at sea: and they may have been due to earthquakes, though the evidence is clearly incomplete.

This note is taken from a letter by Mr. A. R. Sharpe, in Nature, vol. 40, p. 294.

Conclusion.

With one possible exception (that of Ben Nevis), the earthquakes of 1889 are typical examples of British shocks—they occurred in districts where earthquakes are rarely felt, and their disturbed areas are circular or only slightly elliptical in form. Turning to a more distinctly seismic area, Switzerland for example, we find that the disturbed areas are often extremely elongated, the longer axes being parallel to those of the neighbouring Alpine chain; earth-

quakes are more frequent, their intensity, as a rule, is greater, and much larger areas are disturbed. Different stages in the geological history of a district are characterized by different kinds of earthquakes. The Alpine system is not yet old, fault-formation is still in progress, and the fault-slips are long and frequently recurring. In Great Britain, we meet with a later stage. Fault-formation in our seismic area is more advanced, and slipping takes place so slowly and over distances so short, that our earthquakes are rare and the areas disturbed by them more or less circular in form.

Every stage in the process, however, requires investigation, and that of which our British earthquakes are witness is certainly deserving of attentive study. Unattractive though it may be at first sight, the epoch immediately preceding the death of a mountain-chain, is at least as interesting to the geologist as the more vigorous periods of origin and growth.

Errata in the Maps.

Edinburgh earthquake :	*For*	Costorphine,	*read*	Corstorphine.
	,,	Georgie,	,,	Gorgie.
	,,	Curriehall,	,,	Curriehill.
Lancashire earthquake :	,,	Tongridge,	,,	Longridge.
	,,	Mihnrow,	,,	Milnrow.
	,,	Harwich,	,,	Horwich.
Kintyre earthquake :	,,	Tarber,	,,	Tarbert.
	,,	Glachan,	,,	Clachan.

In the map of the Lancashire earthquake, the outermost of the two smaller circles should have been a dotted line. In the map of the E. Cornwall earthquake, the spot between North Hill and Callington should be erased.

VI.—The Age of the Himalayas.

By W. T. Blanford, LL.D., F.R.S., etc.

I REGRET that I cannot accept as unquestionable the evidence brought forward by my friend Mr. Howorth in favour of the recent elevation of other mountain ranges in Asia besides the Himalayas. I dealt with the latter alone, because I have a slight acquaintance with parts of them, and some knowledge of the observers whose opinions are quoted. But I argue from the known to the unknown, and if I find reason to reject the evidence on which Mr. Howorth relies to prove the absence of extensive glacial markings in the Himalayas, I am disposed to be sceptical as to that on which he founds his argument in the case of other ranges. I decline to be drawn into a discussion about the latter.

I quite agree in the improbability of the Himalayan ice having ever reached the Indo-Gangetic plain, but I think I have shown that this is not the question at issue. I cannot, however, help remarking that if I depended chiefly, as Tchihatcheff and Cotta appear to have done in the case of the Altai, on the presence or absence of erratics, I might come to a different conclusion, for there are unmistakable "erratics"—huge blocks believed to have come from the higher Himalayas—in the Northern Punjab.

I hope I do no injustice to Mr. Howorth's argument in placing

it in this form: because the glaciers of the Alps in Pleistocene times extended some distance beyond the base of the mountains, those of the Himalayas, if they existed, should have done the same. Surely no one can contend that the glaciers of the Alps must descend to the sea-level at the present day because those of Greenland do so. But the difference in latitude between the Himalayas and the Alps is practically the same as that between the Alps and Greenland.

But, Mr. Howorth urges, there was a great sea in Central Asia in Pleistocene times, and consequently Himalayan ice would have transported glacial *débris* beyond the mountains. I dispute both the fact and the inference. Even if there was a greater ice-accumulation (and I think I have shown that there was), it does not at all follow that this would have reached plains, but little above the sea, within from 26 to 34 degrees of the Equator. With regard to the Central Asiatic sea, of course there was a considerable tract covered with water in late Tertiary and probably in Pleistocene times in the Caspian and Aral area. But this area was I believe then, as it is now, cut off from Tibet and the Himalayas by the great ranges extending from the Pamir through the Thian-Shan to the Altai, and surrounding Eastern Turkestan on the West and North. As to great lakes having occupied the depressions of Eastern Turkestan, the Gobi, etc., I can only say that I once mistook similar plains in Persia for lake-basins, and have seen reason to believe I was in error. The occurrence of salt lakes and salt plains merely indicates the absence of drainage, and is by itself no proof of the former occupation of any area by the sea. The horizontal or nearly horizontal beds supposed by many observers to be marine or lacustrine are probably similar to those found throughout the drier regions of Central Asia, and due purely to the wash of detritus from the hills into the plains by rain and melting snow, where the whole rainfall is insufficient to form rivers and to wash away the accumulations, all the water evaporating within the plains themselves. With the coarser beds fine Eolian deposits are associated. I do not wish to appear dogmatic, but after having had better opportunities than fall to the lot of most European geologists of studying the subject, I am unable to attach any value to the evidence brought forward, although I fully acknowledge how strong that evidence appears at first sight by admitting that I was at one time led away by it.

Of the two quotations from my contributions to the Manual of Indian Geology that are adduced as supporting Mr. Howorth's views, the first, and the first part of the second, do not appear to me at all favourable to his theory. Surely, to say that "a movement has been distributed over the Tertiary and post-Tertiary period, and a great portion is of post-Pliocene date," is not the same as to say that the whole movement, or even the greater part of the movement, is post-Pliocene; nor is the argument that "at the close of the Miocene period no such mountain barrier as exists at present separated the Indian Peninsula from Central Asia" equivalent to saying that the barrier was wanting at the close of the Pliocene.

The citation of my remarks as to the post-Siwalik elevation of the Tibetan plateau, however, is a fair hit, and shows how thoroughly Mr. Howorth has collected the testimony in favour of his views, though he appears to have overlooked the footnote (on p. 586) appended to the words quoted, and, to some extent, qualifying the opinion recorded, as it called attention to the greater area once occupied by Himalayan ice. The explanation, however, of my having published what I now think was probably an incorrect view in 1879, is that at that time I had only the evidence concerning the fossil fauna of Hundes that was obtained by Falconer and Strachey. When Lydekker, in 1881, found that one of the best-preserved Hundes fossils was a skull of *Pantholops*, an Antelope confined to the Tibetan plateau, and only living at high elevations, the whole evidence was materially changed. The question now is, whether it is more likely that *Pantholops* inhabited a low level or an unknown Rhinoceros a high one. Of course, where Yaks can find food, there is no reason why a Rhinoceros should not obtain subsistence.

I must again call attention to the fact that far from attempting to go into the whole evidence as to the elevation of the Himalayas, I merely selected two items, one to prove the insufficiency of the evidence brought forward by Mr. Howorth, the other to show the facts which he had overlooked, both items belonging to one, and, in my opinion, by no means the most important part of the geological evidence. Merely to show how wide the question is, I should like for once to "forsake the happy hunting grounds of Geology for those of Zoology," and to call attention to a fact which to my mind is sufficient by itself to disprove a subrecent origin of the Tibetan highlands.

Throughout the great region generally known as Palæarctic, there is no tract of country of the same extent that contains as many peculiar forms of animal life as Tibet. Amongst Mammals alone there are the genera *Pantholops*, *Nectogale* and *Eupetaurus*, and probably *Æluropus* and *Budorcas*, together with the Yak, two kinds of wild Sheep, a Gazelle, two Hares, several *Lagomys*, at least three Marmots, and several Voles. I must say that it is to me incredible that this peculiarly specialized fauna can have been differentiated since Pleistocene times, and very improbable that it can have entirely developed since the Pliocene period. So high a degree of specialization points to a long continuance of the peculiar conditions that still prevail.

Of the two statements of mine that are traversed by Mr. Howorth, one is of course a matter of opinion; upon the other it will I think be found that my information was correct. Mr. Howorth says that Mr. Lydekker formerly classed the Hundes fossils as Pliocene, but subsequently adopted the opinion, which he still holds, that the beds are post-Tertiary. Mr. Lydekker's assignment of a Pleistocene age to the beds in question dates from 1881 (Rec. G.S.I. vol. xiv. p. 158); but in 1886 (Cat. Foss. Mam. Brit. Mus. vol. iii. p. 158) and in 1887 (Rec. G.S.I. vol. xx. p. 54) he has stated that he is now inclined to regard the beds as Newer Pliocene.

It is useless, I fear, to discuss the other statement traversed, whether the contours of the Himalayas are due to freshwater denudation; and we must continue to differ. But I must say that I still think a personal acquaintance with the Himalayas would give a very different idea from photographs and drawings of picturesque bits. The splintered precipices referred to by Mr. Howorth are probably due to the effects of frost; and however common in the higher Himalayas, especially where glaciers exist now, or existed formerly, are not, I think, prevalent in the lower valleys. If it be transcendentalism to refer to the denuding action of rain and streams, valleys and ridges which, however gigantic, are the exact counterparts in form of those seen in a bank of clay after exposure to a season's rain, how should the reference of such contours to an unknown agency be fitly designated?

REVIEWS.

I.—Dr. Anton Fritsch on Palæozoic Elasmobranch Fishes.

"Fauna der Gaskohle und der Kalksteine der Permformation Böhmens." By Dr. Anton Fritsch. Band II. Heft IV. (pp. 93–114, Pls. 80*b*.–90); Band III. Heft I. (pp. 1–48, Pls. 91–102). 4to. (Prague, 1889–90.)

THE two latest parts of Dr. Fritsch's well-known work on the Permian Vertebrata of Bohemia form one of the most important contributions to our knowledge of the Palæozoic Elasmobranchs that have hitherto appeared. A fine Dipnoan skeleton is first described and figured under the name of *Ctenodus tardus*, as a supplement to the preceding part; but with the exception of the two pages and one plate devoted to this, the whole of the instalment is occupied with what the author terms the "Ordnung Selachii." Following ancient custom, the Holocephali are included in the group thus designated in the preliminary remarks; and, for the purposes of the memoir, the Plagiostomi are subdivided into the four "tribes" of Squalides, Xenacanthides, Acanthodides, and Rajides.

Of the "Squalides," or ordinary Sharks, only a single tooth has yet been found in the Bohemian Gas-coal. This tooth is hybodont in form, and receives the name of *Hybodus vestitus*. The determination, however, falls under the same category as the author's now-abandoned statement concerning the occurrence of a Permian species of *Ceratodus*; and it by no means proves the downward range of the Mesozoic genus *Hybodus* into the Palæozoic formations. As in the case of the Dipnoi and the Pleuracanths, detached teeth of the hybodont Sharks are worthless for generic determination.

Of the "Xenacanthides" only the single family of "Xenacanthidæ" is recognized; but why the author should depart from the ordinary system of nomenclature, and not derive the title of this family from its type-genus *Pleuracanthus*, it is difficult to understand. The three genera *Orthacanthus*, *Pleuracanthus*, and *Xenacanthus* are regarded as quite distinct, and re-defined upon the basis of the new Bohemian

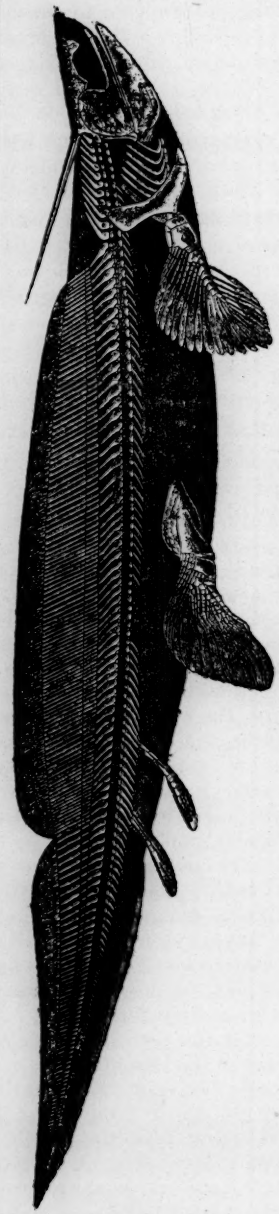


FIG. 2.—Restoration of *Xenacanthus Decheni*, Goldf. sp.

FIG. 1.—Restoration of *Pleuracanthus parallelus*, Fritsch.

specimens. The characters of the teeth, dorsal spine, of the denticles upon the branchial arches, and of the pectoral fins, are quoted as diagnostic; while of *Pleuracanthus* and *Xenacanthus* the materials suffice to justify the two restorations reproduced through the courtesy of Dr. Fritsch, on the opposite page.

As in Britain, *Orthocanthus* is only known in Bohemia from comparatively fragmentary remains. To it are referred (i.) rounded spines having posteriorly placed denticles; (ii.) large teeth with a relatively small median denticle; (iii.) clustered branchial tubercles; and (iv.) long pointed pectoral fins without horny fin-rays. Four Bohemian Permian species are determined, and a fifth (*O. senkenbergianus*) is briefly described from the corresponding horizon of Lebach. Even yet, however, the genus is far from being satisfactorily diagnosed: and with reference to the dentition, we venture to think that it would not be difficult to cite more than one British specimen proving the occurrence in one and the same mouth of the two forms of teeth which Dr. Fritsch regards as characteristic of *Orthacanthus* and *Pleuracanthus* respectively.

Some brief remarks on three undetermined Ichthyodorulites follow the account of *Orthacanthus*, and bear the newly-applied generic names of *Tubulacanthus*, *Brachiacanthus*, and *Platyacanthus*. These names may be only provisional, but we would remark that the first is an inadmissible hybrid, while the two latter are pre-occupied.

The sections devoted to *Pleuracanthus* and *Xenacanthus*, with the general conclusions resulting from the study of these types, make a most important advance in our knowledge of the group to which they belong. As will be observed in the author's restored figures of the two genera (Figs. 1, 2), *Pleuracanthus* is a somewhat more slender fish than *Xenacanthus*, and differs considerably in the character of the fins; in the former genus there are no dermal skeletal parts and the pectoral fin is much elongated, whereas in the latter genus dermal fin-rays are conspicuous and the pectoral is comparatively short and broad. The cavity in the dorsal spine is also described as relatively smaller in *Pleuracanthus* than in *Xenacanthus*. Four Bohemian species of the former genus are determined, and short notes follow on the German *P. sessilis* and the French *P. Gaudryi*; while of *Xenacanthus* the type-species *X. Decheni* is regarded as the sole known representative. Numerous detailed descriptions with beautiful figures of various parts of the skeleton appear in connection with the several species; and the systematic work concludes with a chapter of general observations on the organization of the Pleuracanth fishes as now known.

The results are briefly summarized in the following statement: The skin in these fishes was destitute of scales; the cartilaginous skeleton exhibits everywhere a granular calcification; the skull consists of a continuous piece of cartilage, without investing membrane bones; the nuchal spine is fixed upon a papilla of the cranial roof, and is not connected with a fin; the axial skeleton of the trunk is notochordal, with a calcification of the central fibres; the neural arches are strongly developed, and in two genera there

FIG. 1.—Restoration of *Pleuracanthus parallelus*, Fritsch.

are intercalary cartilages; there are seven branchial arches; the shoulder-girdle is comparable to a branchial arch; the paired fins must have developed from a series of parallel rays, and the joints of the axial rod have arisen partly by thickening, partly by the fusion of several adjoining rays; there are no pelvic elements, the so-called "pelvis" being the basipterygium; the claspers of old males are similar to those of existing Sharks, and there are also the same developments in aged females; the oval eggs have a strong capsule.

In conclusion, Dr. Fritsch finds the nearest living allies of the Pleuracanth fishes in the remarkable family of Notidanidæ, and adds the inevitable "Stammbaum" to show the ancestral position in which he would place them. Few who closely study the evidence will fail to be convinced of the reasonableness of this arrangement; and the majority will doubtless be disposed to follow the Professor in his most interesting theoretical excursus on the origin and development of the paired fins. Recent discoveries compel us to add only one word of caution, namely, that it is rash to assume there were no groups higher than the so-called "Urfische" retaining the primitive parallel disposition of the cartilaginous rays in the paired fins. The fishes with a Cladodont dentition lately made known by Dr. Newberry from the Lower Carboniferous of Ohio under the names of *Cladodus Kepleri* and *C. Fyleri*, seem to have been true Elasmobranchs; but their pectoral fins are not "archipterygial" in the sense of Gegenbaur's terminology, and appear to consist merely of segmented parallel bars. However this may be, the recent rapid advances in our knowledge of the palæontology of the Palæozoic Elasmobranchs must be a source of much gratification to all who are interested in the evolution of the vertebrata; and to no one are we indebted more than to Dr. Anton Fritsch for enduring contributions to the subject. A. S. W.

II.—Catalogue of the Fossil Birds in the British Museum (Natural History), Cromwell Road, S.W. By Richard Lydekker, B.A., F.Z.S., F.G.S. (London, 1891.) Printed by order of the Trustees, and sold by Kegan Paul, Trench, Trübner & Co. 8vo. pp. i–xxviii, and 368, with 75 Woodcuts.

MR. LYDEKKER has earned the hearty thanks of all those who are interested in the palæontological history of the higher Vertebrates, by the valuable series of Catalogues of the Fossil Mammalia, Aves, Reptilia, and Amphibia which he has prepared, under the auspices of the Trustees of the British Museum (Natural History), which form ten separate parts or volumes, containing 3119 pages of text illustrated by 537 woodcuts. The earlier published volumes have already been noticed in this Magazine, and we now have much pleasure in drawing attention to the final volume on the Fossil Birds, which has just been completed. If we except the Amphibia, the class Aves forms the smallest group of Vertebrates known in a fossil state; yet the number of living species exceeds 8000. Thirty-five years ago, it appeared as if the hope of

attaining a knowledge of the ancestry of Fossil Birds was destined never to be gratified. But in 1861 a split slab of Lithographic Limestone was discovered at Eichstädt near Solenhofen, in Bavaria, in the Lower Kimeridgian formation, showing a nearly entire skeleton and impressions of the feathers of what was at first supposed to be a Reptile, but afterwards proved to be a remarkable long-tailed Bird, with twenty slender caudal vertebræ, each joint having a pair of feathers, one feather on each side. Twenty years later, a second specimen was discovered, identical with that described by Prof. Owen in 1862, but in some respects more complete, from which we learn that the jaws were armed with from ten to twelve teeth in the pre-maxillary border on each side, and three or more teeth in the lower jaw also; the teeth were conical and apparently planted in distinct alveoli. The three metacarpals and the phalanges of the fingers were free and were armed with strong recurved claws like those of a Lizard's fore-limb. This singular creature is at present the earliest, as it is also the most generalized bird with which we are acquainted; the sternum was well developed, and probably provided with a carina: indeed, from the characters of both the fore- and hind-limbs, we are justified in concluding that *Archæopteryx* was a perching, flying, Carinate type of Bird; it is the only representative of a distinct order, the Saururæ.

After another interval of ten years, two other types of toothed Birds were discovered by Professor Marsh in North America: one, the *Ichthyornis*, being a bird of powerful flight, with biconcave vertebræ; the other, *Hesperornis*, had a perfectly flat sternum, and was a large flightless aquatic Bird, probably resembling the Loons and Grebes in structure. These American birds, however, are from the Upper Cretaceous of Kansas, and, although of Secondary age, are much younger, and more specialized types than the *Archæopteryx*, which is of Upper Jurassic age.

Previous to these discoveries it had been supposed that the great group of running Birds, such as the Ostrich, Rhea, Emu, Cassowary, and Apteryx, represented the earliest types known; and seeing also that these Ratite, or raft-breasted flightless birds, have been found in a fossil state in England, France, India, Madagascar, New Zealand, Australia, and America, it was only natural to connect them with the still earlier discovery of Bird-like, bipedal impressions met with so abundantly upon the slabs of Triassic sandstone in the Connecticut Valley. These are now, however, commonly attributed to the huge Dinosaurian reptiles, whose remains have of late years been met with, both in N. America and in Europe, many of which evidently progressed upon their hind-legs only, and, having the same number of toe-bones as a bird, might have left similar foot-prints.

Of the other early remains of Birds known in a fossil state, by far the greater part are in an extremely fragmentary condition. Thus the *Enaliornis Barretti*, from the Cambridge Greensand, is founded upon an isolated fragmentary bone, the tarso-metatarsus. The *Odontopteryx toliapica* is founded on an imperfect skull from the London Clay of Sheppey, was considerably larger than that of

a Solan Goose, which had the margins of the bones of both the upper and lower jaws coarsely serrated, and was no doubt also a large fish-eating Bird. Numerous remains of carinate Birds are represented in the Collection by detached bones from various localities and deposits, all of Tertiary age, and many of them referred to existing genera. The Great Auk (*Alca impennis*) is recorded from a guano deposit on Funk Island off the coast of Newfoundland; nearly all the bones with the exception of the phalanges are preserved; this is one of a dozen or more individuals found by Professor John Milne, F.R.S.

By far the most important part of the Collection, if we except the *Archæopteryx*, consists of the remains of the Ratite Birds, the *Æpyornis* of Madagascar being represented by two species, namely, *Æ. maximus*, casts of the femur, the tibio-tarsus, and the tarso-metatarsal bones, reproduced from types in the Paris Museum; the shaft of an actual bone, and an entire egg, 36 inches in longest circumference by 30·3 inches in girth; and *Æ. medius*, an egg, 30·3 inches in longest circumference, and 26·3 inches in girth.

The Indian Ostrich (*Struthio Asiaticus*), from the Pliocene of the Siwalik Hills, is represented by a conjoined mass of bones, comprising nine cervical vertebræ in natural juxtaposition, some imperfect bones of the wing, and the distal portion of the right tarso-metatarsus, together with the greater portion of the proximal phalangeal of the third digit in apposition with the latter. The *Dasornis Londiniensis* is only known by the cranium from the London Clay of Sheppey; but taken in connexion with the discovery of the limb-bones of another Struthious Bird, the *Gastornis Klaasseni*, in the Lower Eocene of Croydon, Surrey, we may conclude that Ostrich-like Birds lived in this country, and also in France and Belgium, in Eocene times. Of the great flightless birds of New Zealand, no fewer than six skeletons have been set up in the Gallery, representing at least five species; there is also a very large collection of detached bones referred to some twenty different species, all described by Prof. Owen. Some of these remains are so recent as to be still covered with dried skin and traces of feathers, showing that their extermination in those islands must have been of very modern date, and no doubt due to the hand of man.

Owen's genus *Dinornis*, we observe, has been subdivided by Lydekker into five genera; but we venture to question the desirability of this course, seeing how great is the individual diversity presented by the skeletons of these large running Birds; we incline rather to the view that they are the result of local variation produced by scarcity or abundance of food and the nature of their habitat; even difference of sex may account for size and robustness in individuals.

Whilst on the subject of nomenclature, we would also question the right to substitute H. von Meyer's specific name *lithographica* for *Archæopteryx macrura*, the latter name having been given to the original skeleton of the long-tailed Bird from Solenhofen by Owen, whereas Meyer's name was only applied to a detached feather of *some Bird* found in the same deposit a year or two previously. The only justification which we can conceive for this

act, is that of the old proverb, that "Birds of a *feather* flock together." But the evidence of identity is by no means conclusive, and it seems hard, therefore, on Sir Richard Owen to wipe out his specific name with a *feather*, he having been the original describer of the almost entire skeleton.

Too much praise cannot be accorded to the Trustees of the British Museum, Natural History, for authorizing the publication of the long series of Catalogues of Recent and Fossil forms, in the Collections under their control, and we earnestly trust that the work may be continued until all the groups, both of Vertebrate and Invertebrate life, have been similarly recorded and illustrated.

III.—Mr. G. A. Boulenger on Extinct Reptilia.[1]

MR. BOULENGER contributes three papers of much palæontological interest to the June number of the Proceedings of the Zoological Society. The first deals with some fragmentary Eocene Chelonian remains; the second and third relate to taxonomic questions of wide importance.

During an examination of the reptilian fossils in the Museum of the Royal College of Surgeons, Mr. Boulenger met with a skull of *Trionyx*, apparently from the well-known Upper Eocene formation of Hordwell Cliff, and, if so, proving that the species represented is a typical member of the genus. The skull much resembles that of the existing *T. hurum*, and it is provisionally referred to *T. planus* (Owen), of which the shell is also closely paralleled by that of the recent species just mentioned. A Sheppey fossil in the same collection, described by Owen as "the lower or distal end of the tympanic bone of the *Crocodilus toliapicus*," is shown to be the proximal end of the left humerus of an Athecan Turtle, evidently *Eosphargis gigas*; while of two other fossils referred by Owen to the same "Crocodile" the so-called "portion of the left ramus of the lower jaw" is stated to be part of a scapula of *Eosphargis*, and "another portion of the right ramus of the lower jaw" truly belongs to a Liassic Plesiosaurian. Incidentally it is pointed out, that no species of the genus *Crocodilus* occurs in the Eocene, the so-called *C. Spenceri* being referable to *Diplocynodon*.

A study of the osteology of *Heloderma* and an attempt to determine its systematic position, lead Mr. Boulenger to express his views upon the classification of the order Squamata. Referring only to the structure of the vertebral column and limbs the following table of diagnoses is given :—

Order Squamata.

A. Pectoral arch or its rudiments present. Caudal hypapophyses forming chevrons.
Suborder I. *Dolichosauria*. 15–17 cervical vertebræ. Extremities archaic, *i.e.* approaching the Batrachian type.

[1] "On Some Chelonian Remains preserved in the Museum of the Royal College of Surgeons," Proc. Zool. Soc. 1891, pp. 4–8, figs. 1–6.

"Notes on the Osteology of *Heloderma horridum* and *H. suspectum*, with Remarks on the Systematic Position of the Helodermatidæ and on the Vertebræ of the Lacertilia," *ibid.* pp. 109–118, figs. 1–6.

"On British Remains of *Homœosaurus*, with Remarks on the Classification of the Rhynchocephalia," *ibid.* pp. 167–172, figs. 1, 2.

Suborder II. *Pythonomorpha.* 9 or 10 cervical vertebræ. Extremities paddle-shaped, with hyperphalangy.
Suborder III. *Lacertilia.* 8 or 9 cervical vertebræ. Fibula reduced proximally; fifth metatarsal reduced in length and strongly modified.
Suborder IV. *Rhiptoglossa.* 5 cervical vertebræ. Extremities pincer-shaped; all the metatarsals reduced in length and strongly modified.
B. No trace of a pectoral arch. Caudal hypapophyses disconnected distally.
Suborder V. *Ophidia.*

Figures of the hind limb are added, the so-called *Hydrosaurus lesinensis* of the Cretaceous being selected as a typical representative of *Dolichosaurus*.

The left mandibular ramus of a small Rhynchocephalian reptile, also in the Museum of the Royal College of Surgeons, forms the text of Mr. Boulenger's third contribution. An examination of the matrix suggests that the specimen was probably obtained from the Lower Oolites of Wiltshire; and the left maxilla of a nearly similar reptile, from the Purbeck Beds of Swanage, is recorded as having been recently acquired by the British Museum. These fossils are believed to be referable to *Homœosaurus*, and the first is described and figured as the type of a new species, *H. major*. To the same species is also assigned a mandible from the Kimmeridgian of Hanover described by Struckmann in the Zeitschr. deutsch. geol. Ges. vol. xxv. p. 249, pl. vii. Some remarks on the systematic position of *Homœosaurus* follow; and after several critical observations in regard to the non-diagnostic character of most of the existing definitions of the Rhynchocephalia and the component families of the order, the following revised table is appended:—

Order Rhynchocephalia.

Suborder I. Proterosauria. Each transverse segment of the plastron composed of numerous pieces. Pubis and ischium plate-like. Fifth metatarsal not modified.

Vertebræ conically excavated at either end, with persistent notochord, all with intervertebral hypapophyses; limb-bones without condyles; humerus with entepicondylar foramen. . . . . 1. *Palæohatteriidæ.*

Vertebræ fully ossified, cervicals opisthocœlous, dorsals biconcave; no hypapophyses between the dorsal vertebræ; limb-bones with condyles; humerus with entepicondylar foramen or groove. . . . . 2. *Proterosauridæ.*

Suborder II. Rhynchocephalia vera. Each transverse segment of the plastron composed of three pieces, a median angulate and a pair of lateral. Pubis and ischium elongate, and fifth metatarsal modified, as in the Lacertilia.

A. Nasal openings distinct. Mandible with coronoid process, the rami not united by suture. Vertebræ deeply biconcave.

Humerus with ectepicondylar and entepicondylar foramen; ribs with uncinate processes; all the vertebræ with intercentral hypapophyses. 3. *Hatteriidæ.*

Humerus with entepicondylar foramen; ribs without uncinate processes; no hypapophyses between the dorsal vertebræ. . . . . 4. *Homœosauridæ.*

B. Nasal opening single. Mandible without coronoid process, the rami united in a solid symphysis. Vertebræ fully ossified, feebly biconcave; no hypapophyses between the dorsal vertebræ. Humerus with ectepicondylar foramen or groove.

Snout short, ending in a beak. . . . . 5. *Rhynchosauridæ.*

Snout crocodilian in shape, with toothed premaxillaries. . . . . 6. *Champsosauridæ.*

REPORTS AND PROCEEDINGS.

Geological Society of London.

June 10, 1891.—Sir Archibald Geikie, LL.D., F.R.S., President, in the Chair.

A Special General Meeting was held at 7·45 P.M., before the Ordinary General Meeting, at which the following resolution was proposed by Dr. Evans, seconded by Mr. Bauerman, and carried unanimously :—That the Society approve of the recommendation of Council that Mr. Isaac Charlton, the House Steward, on his retirement, after fifty years' service, be granted a pension of £70 per annum for life.

Before the commencement of the general business, Prof. Blake rose, on behalf of those present at the meeting, to congratulate the President on the honour that it had pleased Her Majesty to confer upon him. No one who knew him could fail to appreciate how thoroughly it was deserved; and the Geological Society would doubtless feel also the honour conferred on their science in the person of their President and the Head of the Geological Survey of the United Kingdom.

The President referred to the services of the late Dr. Duncan, and suggested that in the name of the Society a message of cordial sympathy should be sent to Mrs. Duncan on the great loss which had befallen her. This proposal was approved of by the Fellows present; and the Secretary was requested to communicate with Mrs. Duncan.

The following communications were read :—

1. "Note on some Recent Excavations in the Wellington College district." By the Rev. A. Irving, B.A., D.Sc., F.G.S.

This paper furnishes new facts of Bagshot stratigraphy obtained from open sections since the author's last paper was read on Nov. 12th, 1890. The whole sequence of the beds, as given in the published section of the College Well, has now been verified at their respective outcrops; percentages of clay in the beds laid open in excavations in March last along the critical portion of the ground are given as results of mechanical analyses of samples of them; and the northerly attenuation of the green-earth series and of the quartz-sand series is reduced to a question of mere measurement, for which the requisite data are now to hand.

The author claims to have demonstrated that the mapping of the Geological Survey contradicts itself; that later workers in adopting this as the basis of their work along the S.E. Railway have fallen into serious error; and that a complete contradiction is given by the facts to the adverse criticisms offered on his corrected section along the railway, which was exhibited in November last, and is reproduced for the present paper.

2. "Notes on some Post-Tertiary Marine Deposits on the South Coast of England." By Alfred Bell, Esq. Communicated by R. Etheridge, Esq., F.R.S., F.G.S.

The author's object in this paper is to trace the successive stages in the development of the present coast of the north side of the English Channel, and to ascertain the sources of the diversified faunas.

The first traces of marine action on the South Coast in Post-Tertiary times are found on the foreshore in Bracklesham Bay. The author's reading of the section is somewhat different from that of the late Mr. Godwin-Austen; and he divides the marine series into (1) an estuarine clay with Mollusca common to estuarine flats; (2) a compact hard mud; and (3) a bed of fine sandy silt with many organisms. These beds indicate a change from estuarine to deep-water conditions. A full list of the Selsey fossils is given, including, amongst other animals, upwards of 200 Mollusca. Of 35 species of Mollusca not now living in Britain, the majority exist in Lusitanian, Mediterranean, or African waters; furthermore, nearly 45 per cent. of the Mollusca are common to the older Crags of the Eastern counties. The author considers the fauna of the Portland Bill shell-beds to indicate the further opening of the Channel subsequent to the formation of the Severn Straits, and believes that this fauna represents the deposits wanting between the Selsey mud-deposits and the erratic blocks which, according to him, overlie the mud; these Portland shells indicate an intermediate temperature "rather southern than northern" according to Dr. Gwyn Jeffreys.

In conclusion, details concerning still newer beds are given, and lists of fossils found therein; and the author observes that there is no evidence to show when the English Channel finally opened up, beyond the suggestion of Mr. Godwin-Austen that, if the Sangatte beds and the Coombe Rock are of the same period, it must have taken place after their formation.

CORRESPONDENCE.

PFAFF'S "ALLGEMEINE GEOLOGIE."

Sir,—By an inadvertence I have, in quoting Dr. Pfaff's work on p. 301 of the July Number of the Geol. Mag. confused the title with that of a well-known work by Justus Roth. The true title of Pfaff's work referred to is *Allgemeine Geologie als exacte Wissenschaft.* I shall be greatly obliged if you can afford space for this correction in the forthcoming Number.

A. Irving.

MOLARS OF PERISSODACTYLA;—A CORRECTION.

Sir,—In my notice on this subject on page 321, line 15 from top, I have inadvertently written *crotchet* instead of *anti-crotchet.*

R. Lydekker.